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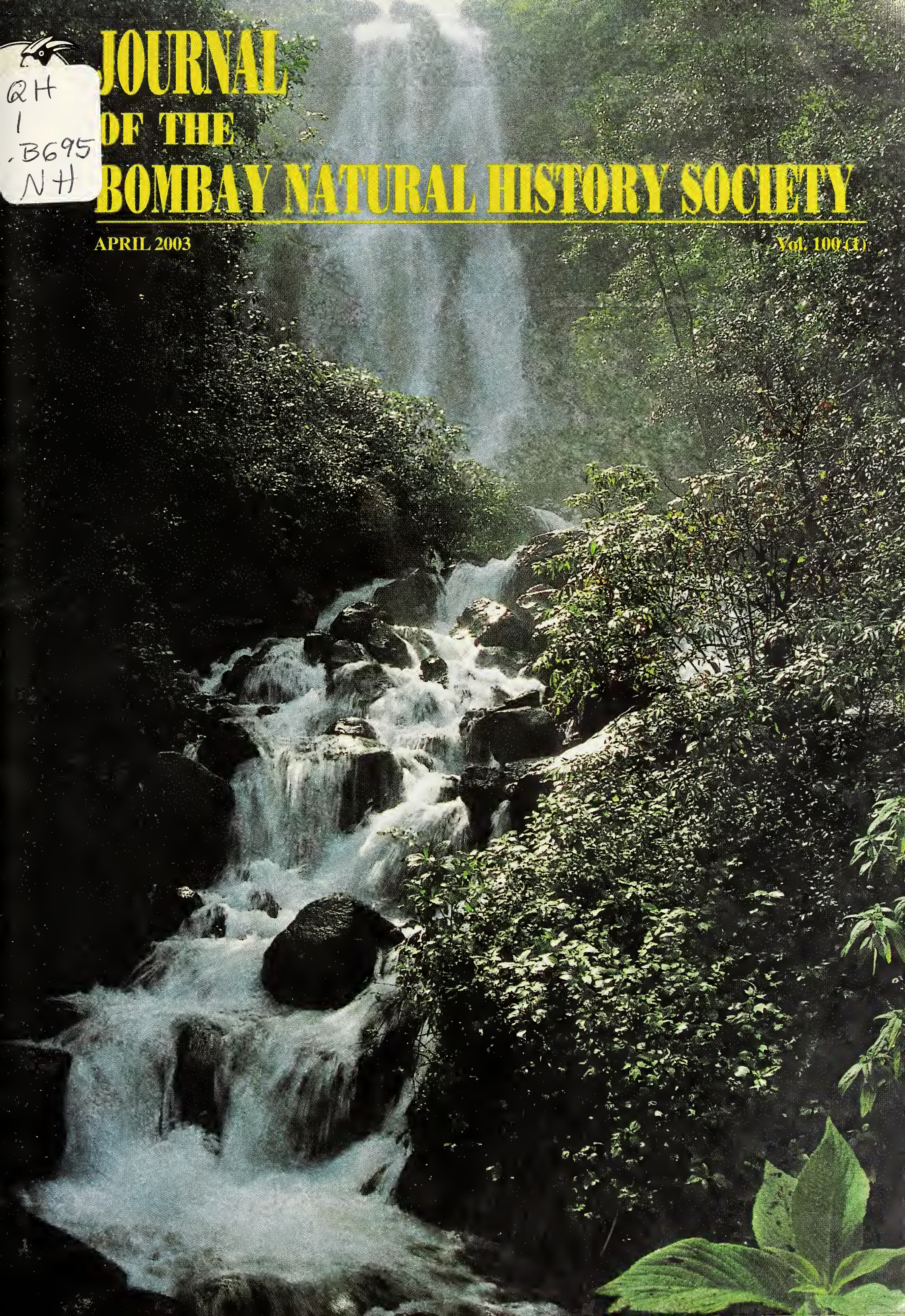

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Editors

A Web of Rivers

The idea of linking the rivers of India to provide water security to a region dependent on the vagaries of the monsoon has so far been a dormant pipe dream. Beset by legal and political problems over the waters of the Cauvery river, the highest judicial and administrative authorities of the country seem to have clutched at a nebulous last straw, a project to link the rivers of the country, as a palliative to a persistent problem.

In a memorandum to the Prime Minister, signed by 58 concerned conservationists, including three retired bureaucrats who had been involved in the administration of the water resources and environment of the country as Secretaries to the Govt of India, state:

"The idea of the 'linking of rivers', dormant for a long time, has acquired new prominence now, particularly in the context of the acute form that the Cauvery dispute took in the course of the year 2002, as well as the drought that afflicted several parts of the country in that year. In response to a public interest writ petition, the Supreme Court has desired that the project for the linking of the rivers of India be accelerated. The Prime Minister has announced the setting up of a task force to consider the modalities of implementing the project, and declared that it would be taken up "on a war footing". The Leader of the Opposition in the Lok Sabha has welcomed this undertaking.

The project has been the subject of much reporting and comment in the media in recent months. It has been presented by the Government as a major initiative and the definitive answer to the future water problems of the country, and it has been so hailed by some. However, some others have expressed apprehensions. We, the signatories to this memorandum, feel that this decision is fraught with serious consequences, and that the Government should carefully reconsider it before proceeding further. Without commenting on the Supreme Court's observations in this case, we shall set forth our reasons for urging a reconsideration of the decision by the Government.

Outline of Proposal

Our understanding of the project, derived partly from the Report (September 1999) of the National Commission for Integrated Water Resources Development Plan (NCIWRDP) and partly from presentations currently being made by governmental agencies, is briefly outlined here for confirmation or correction.

Without going into the history of the idea of the linking of rivers of India, we note that the 'Ganga-Cauvery Link' proposal mooted by Dr. K.L. Rao and the 'Garland Canal' idea put forward by Captain Dinshaw Dastur were examined and found impractical, the former on the grounds of the very large financial and energy costs involved, and the latter because it was technically unsound; and that the proposal now taken up is based on the work that the National Water Development Agency has been doing during the last two decades after its establishment in 1982 in pursuance of the 'National Water Perspectives' brought out by the Ministry of Irrigation in 1980. There are two main components in it, namely the Himalayan Rivers component and the Peninsular Rivers component. The Himalayan component envisages a number of links, including some within the Ganga system (Kosi-Ghagra, Gandak-Ganga, Ghagra-Yamuna Sarda-Yamuna, etc); some between neighbouring rivers in the Brahmaputra system (Manas-Sankosh-Teesta); a couple between those two systems (Teesta-Ganga, and an alternative Brahmaputra-Ganga link); one long link from Sarda to Sabarmati through the Yamuna and Rajasthan; one from the Ganga to Subarnarekha via Damodar and then on to Mahanadi; and a few others. The general idea is to transfer waters from 'surplus' eastern rivers to 'deficit' central, western and southern regions. The Peninsular Rivers component again involves a number of links, of which the most important would be those connecting Mahanadi, Godavari, Krishna, Pennar and Cauvery. The idea is to transfer the surpluses estimated to exist in the Mahanadi and the Godavari to the deficit southern basins (Cauvery, Vaigai). Other links in the Peninsular component would include Ken-Betwa, Parbati-Kalisindh-Chambal, Par-Tapi-Narmada, Damanganga-Pinjal, etc. Another idea is the partial diversion of certain rivers flowing into the Arabian Sea eastwards to link with rivers flowing into the Bay of Bengal (Bedti - Varda, Netravati-Hemavati, Pamba - Achankovil - Vaippar).

Mandate of the Task Force

We note that the Task Force has been asked to examine not the soundness or viability of this project but the modalities of its implementation. Three main difficulties have been recognized: the formidable challenge presented by the accelerated time-frame indicated by the Supreme Court; the magnitude of the financial resources needed (roughly and tentatively estimated at Rs. 5,60,000 crores); and the problem of bringing about the necessary political consensus on the transfers involved. The Task Force appears to be concentrating on these three tasks at present. However, there are some prior questions that need to be asked: Why has this project been proposed? How did it emerge? How does it fit in with the national planning process? Is it necessary and feasible, and is it likely to be beneficial on the whole? As these questions seem beyond the mandate of the Task Force, we propose to raise them here.

Sudden Emergence

The project appears to have suddenly emerged into prominence. If the Government had been contemplating a monumental project of this kind, there would have been some indications. There were none. The Ninth Plan made no reference to it. Even the Tenth Plan (which lays special emphasis on water and wishes to be regarded as a 'Water Plan') refers to many important approaches, policies, programmatic initiatives, and so on, but says nothing about any river-linking project. The Prime Minister's important Address to the National Water Resources Council (1 April 2002) did not mention it. It seems clear that the Government were not seriously thinking of any river-linking project. The NWDA's proposals were non-starters for various reasons. The Government's own initial submissions to the Supreme Court were very cautious and lukewarm. The Supreme Court's direction (if its observations can be so regarded) and the Government's enthusiastic response to it have changed all that. A project that was not on the anvil has suddenly become the most important undertaking of the Government. This seems to us to be a bypassing of the planning process.

National Commission's Observations

Not very long ago the high-level National Commission for Integrated Water Resources Development Plan (NCIWRDP), the first national commission on water, set up in 1996, submitted its Report (September 1999). Its Terms of Reference specifically included 'Inter-Basin Transfers' as an item. It reviewed the NWDA's studies. It did not discuss the proposed Himalayan links in detail because the data are classified as confidential, but did observe that the costs involved and the environmental problems would be enormous; that the further expansion of irrigation in the desert areas of Rajasthan would need examination from all angles; that the NWDA's Himalayan component would require more detailed study; and that the actual implementation was unlikely to be undertaken in the immediate coming decades. On the Peninsular component, after a careful examination of the water balances of the various basins, the Commission observed: "Thus there seems to be no imperative necessity for massive water transfers. The assessed needs of the basins could be met from full development and efficient utilization of intra-basin resources except in the case of Cauvery and Vaigai basins. Therefore, it is felt that limited water transfer from Godavari at Ichampalli and Polavaram towards the south would take care of the deficit in Cauvery and Vaigai basins... Though surplus is available in Mahanadi also, the transfer from that river would require much longer link and is in any case not required for the immediate future...." (The Commission then takes note of some uncertainties that may affect the above judgment and says that further studies as to the future possibilities of inter-basin transfers need to be continued.) The decision to embark on this massive project "on a war footing" seems difficult to understand in the light of those observations of the National Commission.

Rationale of Project

However, there is now a project, and we must consider its rationale. The project is claimed to be the answer to the country's problems of recurring floods and drought in different areas; the generation of hydroelectric power is also put forward as a justification.

Neither flood control nor hydroelectric power calls for a linking of rivers. In the case of hydroelectric power, the usual practice is to postulate a 'potential' in some rivers or areas (for instance, Narmada, Brahmaputra, the Northeast of India, Nepal) and propose large projects (Sardar Sarovar, Dihang, Subansiri, Tipaimukh, Karnali, Pancheswar, and so on) to exploit that potential. Each such project will have to be looked at carefully, but what needs to be noted in the present context is that while the need for hydroelectric power may lead to the formulation of particular projects in specific locations, it would not by itself take us to the idea of linking rivers. (Incidentally, the linking of rivers or inter-basin transfers would in the generality of cases *require* much energy - normally in excess of what the project might generate - but in this case we are told that the project will be a net generator of large quantities of power: a figure of 30,000 MW has been mentioned. That strains our credulity and will need careful examination with reference to each link.)

Similarly, the problem of recurring floods in certain rivers or areas may lead (rightly or wrongly) to the formulation of specific projects with flood control as one of the objectives (or a primary objective) — for instance, the DVC projects, a high dam on the Kosi, and so on — and will not by itself call for a linking of rivers. It must also be noted that opinion on flood control has changed over the years. It is now generally recognized that big dams play only a modest role in flood-moderation; that even in those projects (not many) where flood cushions have been built in, that cushion tends to get eaten into partly by excessive silting and partly by the more powerful demands of irrigation and power generation; that considerations of the safety of structures sometimes necessitate the release of waters causing 'man-made' floods downstream; that by and large, the old notion of 'flood control' has to change to the newer ideas of learning to live with floods and minimizing damage; and that this requires a relatively greater reliance on non-structural than on structural measures. By now, this has almost become conventional wisdom. Even if all the river-linking proposals are implemented, the contribution that this will make to the mitigation of the flood problem will not be substantial. Dr. Bharat Singh, a doyen among engineers and the former Vice-Chancellor of the Rourkee University, has observed: "Any water resources engineer will immediately discard inter-linking of rivers as a flood control measure".

As regards drought, we have the answers already. Rajendra Singh has shown in Alwar District in Rajasthan that rainwater-harvesting can be practised successfully even in low-rainfall areas. Earlier, Anna Hazare had brought about a transformation through water-harvesting (along with other measures) in Ralegan Siddhi (which is also a low-rainfall area). The Madhya Pradesh Government has initiated large Statewide programmes of water-harvesting and conservation. In the water-scarce parts of Gujarat, some good NGOs have remarkable achievements in this regard to their credit. Dhan Foundation has been doing good work in the southern States. The large numbers of tanks in Tamil Nadu, Karnataka and Andhra Pradesh were remarkable water-management systems that have gone into decline, and efforts are on to restore and rehabilitate them. Similar efforts are also needed, and are in progress, in respect of other traditional systems such as *ahars* and *pynes* in Bihar, *johads* in Rajasthan, and so on.

In brief, the primary answer to drought has to be local; it is only thereafter, and in some very unpromising places, that the bringing in of some external water may need to be considered. Besides, the river-linking project, if implemented, will take water only to a small part of the arid or drought-prone areas; large parts of such areas will remain unserved and will have to meet their needs through the local augmentation of water availability. It was in recognition of the importance of such local, community-led initiatives of rainwater-harvesting and watershed-development that the Prime Minister strongly urged the promotion of such initiatives on a nationwide basis in his Address to the National Water Resources Council on 1 April 2002.

(Incidentally, the project as now outlined essentially envisages the addition of waters to certain existing rivers. The additional waters will thus go to areas that are already being served to some extent by that river or by a canal from a reservoir on that river. How will this benefit the uplands and plateaux that are unserved by the existing rivers or are drastically water-short? A glance at the two maps showing the proposed links does not provide a clear answer to this question. However, it is being claimed that irrigation will be extended to additional areas. This may well be true in the sense that areas unreached earlier in the vicinity of a river or within the command area of a project may now receive some irrigation, but will the waters reach the country's drylands?)

A further point to be kept in mind is that it is not primarily drinking water needs but the large demands of irrigation that lead to proposals for long-distance water transfers, though the waters so transferred may also be used to meet drinking water requirements. Water transfers for irrigation may be proposed either for providing additional water to areas already under irrigation or for extending irrigation to arid or 'rainfed' areas. In both cases, difficult questions arise.

In irrigated areas (for instance, the Cauvery basin), the question is whether large demands for additional irrigation water should be unquestioningly accepted and met through supply-side solutions such as large dams or inter-basin transfers, or a serious attempt made to improve water-use efficiency in irrigated agriculture, get more value out of a given quantum of water, reduce the water-demand, and minimize the need for supply-side projects. In the context of the prevailing low efficiency of water-conveyance in canal systems and water-use in irrigated agriculture, bringing in more water from another basin would really amount to the provision of more water for being wasted. It would also mean that there would be no motivation at all for changing cropping patterns and shifting from water-intensive crops to crops that need less water; on the contrary, the tendency to grow water-consuming crops would receive strong encouragement. (It may be added that cropping patterns and water-use practices that lead to or aggravate water-scarcity are often the results of government policies relating to agriculture and water, and what is called for is the rectification of those policies rather than the importation of water.)

In arid or drought-prone areas, the introduction of irrigated agriculture of a kind appropriate to wet areas may be unwise. 'Development' in arid areas should perhaps take other, less water-intensive forms. The slogan of 'making the desert bloom' is not necessarily a sound one. It can be argued that the Rajasthan Canal project was not a good idea but a misconceived one. These are difficult but important questions that need careful consideration.

In both irrigated and rainfed areas, the bringing in of external water may also have other secondary consequences: the need to bring in farmers from elsewhere and the resulting social tensions (as in Rajasthan); increased incidence of conditions of water-logging and salinity (a concomitant of irrigated agriculture in many places); the possibility of the repetition of the 'Green Revolution' patterns of agricultural development and the related phenomena of monoculture, loss of biodiversity (disappearance of indigenous varieties of seeds of plants and grains), the problems arising from chemical fertilizers and pesticides, the loss of micro-nutrients from soils, and the replacement of healthy indigenous varieties of food crops by high-yielding, commercially viable, but nutritionally deficient crops; social inequities of diverse kinds; and so on. These are not unavoidable consequences, but they are dangers that have to be kept in mind.

Subject to all those caveats, the idea of taking water from 'surplus' to 'deficit' basins may seem *prima facie* a good one. That indeed is the principal driving force behind the project, and that is also what gives it its popular appeal in water-scarce States. However, there are many serious difficulties with that plausible proposition, which need to be noted.

Some Difficulties

Gigantism / Altering Nature

To start with, there is the fundamental objection, not to the idea of 'inter-basin transfer' *per se* (though that aspect does need consideration), but to the grandiose nature — the gigantism — of the undertaking. This will be a massive intervention in nature, an ambitious attempt to alter nature. That it is to be compressed into a short span of time may aggravate the intervention but that is a secondary point, the main one being that it amounts to nothing less than the redrawing of the geography of the country. It appears to us that this is a severe case of technological hubris of a kind that (we thought) had been discredited and was a thing of the past.

Criticisms of gigantism are sometimes responded to with the answer that no gigantism is intended; that the project will proceed carefully and slowly, in a piecemeal manner, from the minor and relatively less problematic links to the more difficult and ambitious ones. Is such a careful, exploratory, step-by-step approach in fact intended? This seems inconsistent with what we have been seeing and hearing in recent months: the Supreme Court's desire that the project be accelerated and the time-frame compressed; the Prime Minister's announcement that the project will be taken up on a war-footing; the setting up of a Task Force; the references to the order of investments involved; the publicity surrounding the project; and so on. It appears that the Government wants to make dramatic announcements, and at the same time claim that it is adopting a slow, careful, modest, exploratory approach. The general impression in the country is certainly that a massive project has been undertaken. If that is not the case, the Government should make the position clear.

Strange Idea

There is in fact an oddity about the proposition that we have tended not to notice. One can understand if the planners start from an identification of the needs of particular areas, proceed through a consideration of options and alternatives, and finally arrive at a decision to link two or more rivers as the only or the best option in a given case. Instead, the present project *starts* with the proposition that the rivers of India must be linked, and then proceeds to consider possibilities of storages, links, transfers, etc. What is the basis for that *a priori* proposition (even if it is an old one)? How did we arrive at this strange idea that all the rivers of India — or the major ones — must be linked? The analogy sometimes put forward with the linking of highways or with a national power grid is inapt and misleading. Human creations or productions such as highways or power can be manipulated by humans. That does not necessarily apply to rivers. Rivers are not human artefacts; they are not pipelines to be cut, turned around, welded and re-joined. They are natural phenomena, integral components of ecological systems, and inextricable parts of the cultural, social, economic, spiritual lives of the communities concerned. (So too are related features, both natural and man-made, such as lakes, wetlands, tanks, *beels*, *ahars* and *pynes*, and so on.)

Serious Consequences

The project is potentially fraught with serious consequences. It will necessarily involve dams, reservoirs, diversion of waters, canal systems, and so on. By now there is adequate knowledge of what all this entails: violent disturbance of pristine areas and of the lives of (tribal) communities living there, disruption of the habitats and movement routes of wildlife, loss of bio-diversity (flora and fauna), changes in river morphology and water quality (arising from the stilling of flowing waters), submergence of forests and agricultural lands, changes in the micro-climate, public health consequences, displacement of people and their livestock and the related problems of resettlement and rehabilitation, reduction of downstream flows, the consequent alteration of the river regime (reduction of the capacity of the river to cope with pollutants and regenerate itself; reduction in nutrient content in downstream flows; diminution of groundwater-recharging, reduction in freshwater outflows into the sea), and the impacts of these on aquatic life, riparian communities and their livelihoods such as agriculture or boat-plying, and on estuarine conditions (including estuarine fish populations) and possible salinity incursions; and so on. These impacts and consequences have been observed in many projects, and will need to be studied carefully in the case of each of the proposed links.

(Incidentally, much harm has been done in the past by the tendency to regard only water abstracted from the stream as 'used' and water flowing in the stream and particularly into the sea as 'wasted'. To minds so conditioned, the fact that floods occur in some areas and drought is experienced elsewhere immediately suggests that water must be transferred from the former to the latter places. Behind this lies an ignorance of the multiple purposes served by flowing water — even floods — and the importance of water flowing into the sea, and a failure to recognize the consequences of a diversion of flows. Rivers must flow if silt is to move and nutrients are to reach the plains, the deltaic region, and mangrove areas such as the Sunderbans. Such flows and nutrients also enter the coastal waters and contribute to the increase of marine wealth, whether it be shoals of fish or algae and other organisms which hold the key to the future nutritional, medicinal and other needs of our country and even of humanity at large. Before diverting waters and reducing downstream flows, we must make sure that the alluvial deltas will not die, forcing the migration of populations and causing distress in the coming generations. Rivers must have enough water to support riverports, inland navigation and riverine fauna and flora, and to check the incursion of salinity in coastal areas. The concept that no water is to be allowed to go waste into the sea needs to be seriously challenged on hydrological and meteorological grounds.)

It has been argued that similar projects have been undertaken elsewhere without catastrophic consequences, but that is a questionable statement. Water-resource projects are part of the kind of 'development' that the world has been pursuing, which has in fact had many catastrophic consequences. But leaving that aside and confining ourselves to projects on rivers, it is well-known that old-style planning in the former Soviet Union led to the diversion of two rivers that were flowing into the Aral Sea, resulting in the virtual death of that sea. That is now recognized as a great environmental disaster, perhaps the greatest ever, and desperate attempts are being made to reverse it. With the 'linking of rivers' project we may be headed for other unforeseen disasters and may discover this too late. A degree of caution seems warranted before the Government embarks on this enterprise. (It may be added that there is a move in some countries away from the past history of interference with the natural flows of rivers towards a restoration of the original flows to some extent.)

Those who advocate caution are apt to be accused of timidity and exhorted to look at China which has embarked on the massive Three Gorges Project. That is not necessarily a good project; the disasters that it will bring will be seen in the future. The opposition to Three Gorges in China is muted because dissent is not easy in that country. Those who are envious of China's ability to 'get things done' must reflect on how far they are prepared to go in emulating that system.

Announcement in Advance of Examination Clearance

This is a 'concept' that consists of some twenty or thirty projects. For each project, some small and some big, a proper feasibility study will have to be prepared as an interdisciplinary exercise, fully internalizing economic, social, sociological, human, environmental and other aspects *ab initio*. Thereafter, the projects will have to be examined and evaluated, again in an inter-disciplinary manner, and cleared by the appropriate agencies. Thorough Environmental Impact Assessments, comprehensive Cost-Benefit Analyses covering direct and indirect financial, economic, environmental, ecological, social and human costs and benefits (quantifying these wherever possible), qualitative assessments of non-quantifiable considerations, and based on these, rigorous investment appraisals, will need to be undertaken. We do not know what the outcome of that process will be: all projects may pass the test; all may fail; or some may survive a stringent scrutiny while others may not. In advance of that process, a project has been announced and expectations raised in the general public. The presumption is that the project or projects will be found acceptable and cleared. We fear that this may reduce the whole process of examination, evaluation and clearance to a mere formality, a mockery. With the conclusions already presumed and announced at the highest level, it seems difficult to believe that the governmental agencies concerned (the CWC, the Technical Advisory Committee, the Ministry of Environment and Forests and its Committees, the Task Force that has now been set up) will be able to undertake a serious and objective examination. The pressure on them to be 'positive' will be very great.

Incidentally, we are told that NWDA has prepared feasibility studies for some five or six links, and that these have been "ratified by engineers, sociologists and economists". If indeed there are feasibility studies of some of the proposed links, we would strongly urge that they should be put into the public domain for engineers, geographers, environmentalists, economists, agronomists, soil scientists, sociologists, social anthropologists, financial analysts, and others outside the Government to examine and offer their comments. This massive undertaking is too important a matter to be left entirely to the internal processes of the Government."

Such a massive environmental intervention will result in substantial human displacement, and it is the poor, the invisible people who will harvest the Grapes of Wrath.

— J.C. DANIEL

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BREEDING BEHAVIOUR OF THE GREATER ADJUTANT-STORK *LEPTOPTILOS DUBIUS* IN ASSAM, INDIA[1]

(*With one text-figure and two plates*)

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Key words: Greater adjutant-stork, *Leptoptilos dubius*, breeding behaviour, incubation period, fledgling

We studied the breeding behaviour of the greater adjutant-stork *Leptoptilos dubius* (Gmelin), the rarest stork in the world at north Haibargaon — its traditional breeding colony in Nagaon (26° 21' N, 92° 45' E), Assam, India — during 1995-1997. Focal nests of early (September-October) and late (November-December) breeding storks in both the seasons, from nest building to fledging of the last young, were observed from dawn to dusk. Development of young from hatchling to fledgling and the associated parental behaviour were recorded in detail.

The incubation period was 35 days while the fledging period was 142 days. Parents left unguarded chicks at the age of 4 weeks; at 6 weeks the chicks could defend themselves, and at 9 weeks they attained juvenile stage. The overall breeding behaviour of the greater adjutant-stork was found to resemble its congeneric the Marabou stork *Leptoptilos crumeniferus*.

INTRODUCTION

Of the 20 storks found in the world, the greater adjutant-stork *Leptoptilos dubius* is perhaps the most endangered. Earlier widely distributed in Nepal, Bangladesh, Myanmar, Thailand, Cambodia and South Vietnam (Baker 1929, Flemming *et al.* 1979, Ali and Ripley 1987, Hancock *et al.* 1992), this largest of Asian storks has drastically reduced in number, and is confined to the Brahmaputra Valley of Assam, India (Saikia and Bhattacharjee 1989, Rahmani *et al.* 1990) with a small breeding population of 100-150 birds in Cambodia (Mundkur *et al.* 1995).

The greater adjutant-stork is a colonial breeder. Very little information was available on its breeding biology (Kahl 1966, 1970, 1971; Baker 1935; Hume and Oates 1890; Saikia and Bhattacharjee 1990) prior to our study. We studied the breeding biology of the stork

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intensively in the north Haibargaon breeding colony at Nagaon for two successive breeding seasons from 1995-1997, right from its arrival at the breeding colony, including the development of the chick(s) to fledgling, up to its departure. The results were compared with those of other stork species.

STUDY AREA

The study site, north Haibargaon, is a traditional breeding site of the greater adjutant-stork at Nagaon (26° 21' N, 92° 45' E). It is a small, semi-urban town situated in middle Assam, on the southern bank of the River Brahmaputra. New buildings are being made very near the nesting trees, which are on private property, near human habitation. A few busy public roads intersect the nesting colony. Behind the houses, there are isolated patches of forest and mixed plantations. Shrubs are present under the tall bamboo *Bambusa* sp. and betelnut *Areca catechu* dominates the area. Kolong a small river, flows about 100 m from the colony.

The Brahmaputra Valley has four seasons: winter (December-February), pre-monsoon (March-May), monsoon (June-September) and the retreating monsoon (October-November). The average rainfall during monsoon is 286 cm.

METHODS

Chronology: The greater adjutant-storks aggregate at the colony in early September (Saikia and Bhattacharjee 1996a). Eggs are laid from September in Assam (Hancock *et al.* 1992). Storks were monitored daily from the first week of September, when they arrived at the site, till the end of May when all the nests were vacated. The adult storks on nests, and on nesting and non-nesting trees were monitored twice (morning and evening) daily.

Analysis: Monthly average of storks was calculated from the data collected. For analysis, data of only those days when both morning and evening counts were taken was considered. Each nesting tree and nest(s) on it were assigned a code number to avoid counting error.

General Breeding Biology: Each year a tall watchtower (*machan*) was built to observe the colony. The height of the *machan* was equal to or just above the nests. Care was taken not to disturb the birds while building the *machan*. Once the birds started incubating, they did not desert the nest. They were observed till the focal nests were either vacated or abandoned. A nest was considered abandoned when the stork pair stopped visiting before laying the eggs, or if the eggs did not hatch and the pair left the nest, or if all nestlings died and the parents stopped attending the nest. A nest was considered vacated when the last nestling of the clutch fledged.

During the first breeding season, from November 1, 1995 to April 21, 1996, we observed five breeding pairs from a 20.5 m high *machan*. There were two trees with one nest each and one with three nests. From the last week of November to the first week of December 1995, three more nests were built on a tree where there was only one nest earlier. Out of the eight nests, five early ones (categorised as early breeders) were observed from the incubation stage, while the later nests (categorised as late breeders) were observed from the nest building stage. Since two nests were abandoned before the eggs hatched, and all the nestlings in one nest died, only five nests were observed till the fledging of juveniles. The average distance between the *machan* and the nests was 13 m.

During the second breeding season, from November 8, 1996 to May 12, 1997, we observed breeding pairs on three nests on three trees from a 23 m high *machan* from incubation till the juveniles fledged. The distances between the *machan* and nests were 12 m, 30 m and 60 m.

The breeding behaviour of the focal pairs was monitored continuously from dawn to dusk, 0500 to 1700 hrs, six days a week. However, the duration of observation decreased to 11 hrs (0545 to 1645 hrs) a day during the shorter days of winter. It was assumed that the individuals seen in the late evening stayed through the night, as they were seen there again the next morning.

Individuals of the focal pairs were identified by their natural markings, facial and bill patterns and individual variations. Gender was determined by the copulation position. We found that the males were slightly larger than the females, which also helped to identify a male and a female of a pair (see also Kahl 1972a). We sketched facial patterns and noted the identification characters on 'face cards' (Coulter and Bryan Jr. 1988, Coulter 1989). The sketches were redrawn as the facial pattern of the stork changed.

We observed the breeding behaviour of other storks in the colony as far as possible. The morphological and behavioural changes from chick to fledgling stage were recorded. A chick was distinguished from a juvenile when blackish-brown feathers replaced its snowy white down feathers.

Incubation and Fledging Period: Incubation was estimated as the period from the initiation of incubation till the hatching of the first chick. The initiation of incubation was considered when, soon after nest building, the parents began behaving as if they were brooding eggs (Coulter 1989). It was difficult to know the exact date of hatching despite daily monitoring. The hatching at each nest was assumed on hearing the first call of the chick, or finding fresh broken egg shells below the tree, or observing the parent's posture and behaviour in the nest. In the focal nest, just after hatching, the parent stork would stand with its legs apart, point the bill towards the floor of the nest (to the new hatchling) and regurgitate or re-ingest food. Otherwise, when the chick was first seen, its probable age was subtracted to get the hatching date (Kahl 1966 and Pomeroy 1978a). In three cases where incubation period exceeded 55 days, it was considered as probable re-laying of egg(s) and such nests were excluded from the analyses. The mean incubation period was calculated from five nests of both seasons, where egg laying and hatching was observed from the *machan*.

The fledging period was considered as the duration from the hatching to fledging of the juvenile, assuming that the same juvenile was the first chick. Before finally leaving the nest, juvenile(s) make exploratory flights and remain away from the nest for some time, and could be missed during a daily census. It was logistically difficult to see the first flight of all juveniles in the whole colony. Therefore, if a juvenile was not seen continuously for a week, it was regarded as fledged, and the fledging date recorded as the date it was last seen. We recorded the date of first flight in 12 nests from both the seasons, to calculate the fledging period.

RESULTS

Chronology: Data were collected over seven and nine months (November 1995 through May 1996 and September 1996 through May 1997) in the first and second breeding seasons, respectively. Storks were found to arrive at the breeding site from the first week of September. In both the seasons, the number of storks increased to a peak in the early part of the season and gradually declined to almost zero in May. In the first season (1995-96), the highest aggregation of storks was found in December, while in the second breeding season (1996-97), it was in October (Figs 1a & b). But the overall population trend in the study area was similar in both the breeding seasons. In all the months, in both breeding seasons, fewer number of storks were counted in the morning than in the evening.

General Breeding Biology

Pre-Chick Hatching Period: (a) External morphological changes: At the onset of the

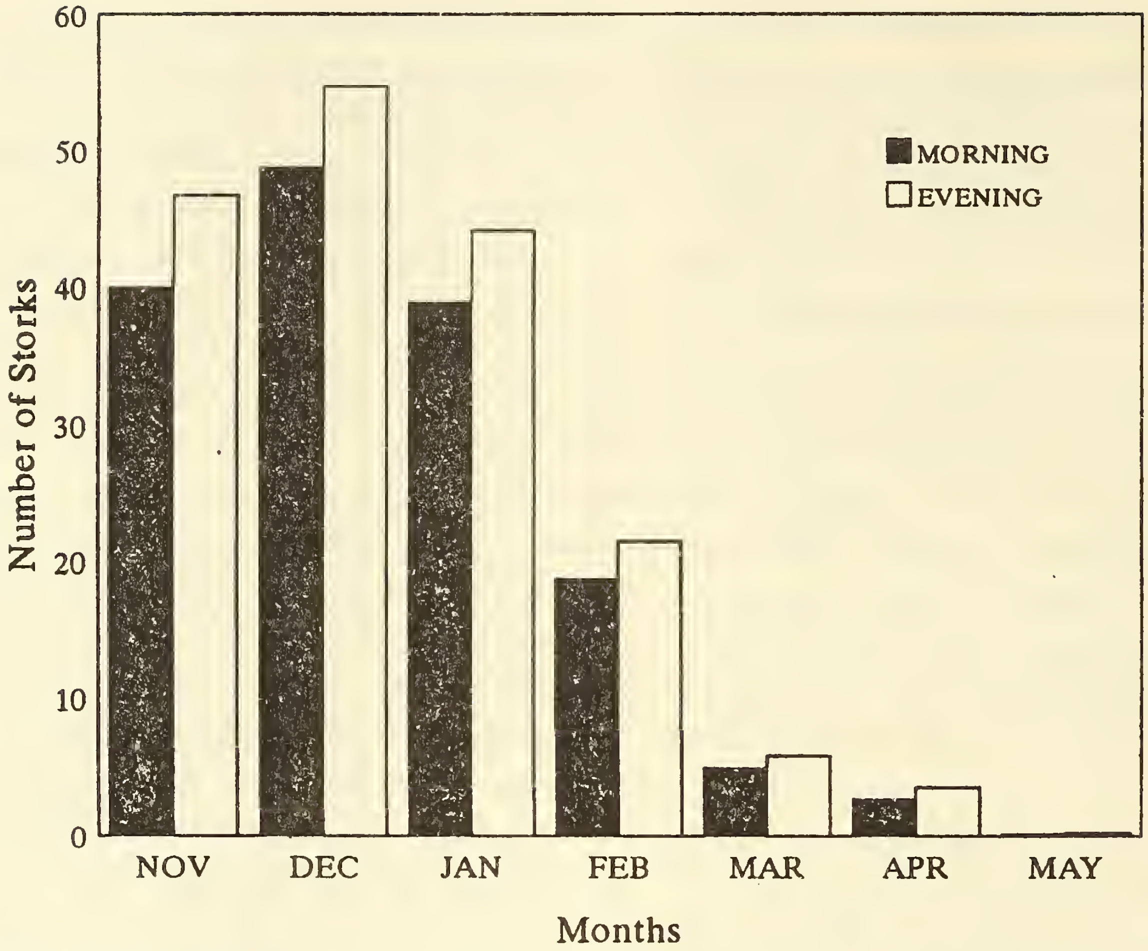


Fig. 1a: Population trend of greater adjutant-stork in North Haibargaon Nesting Colony (1995-96)

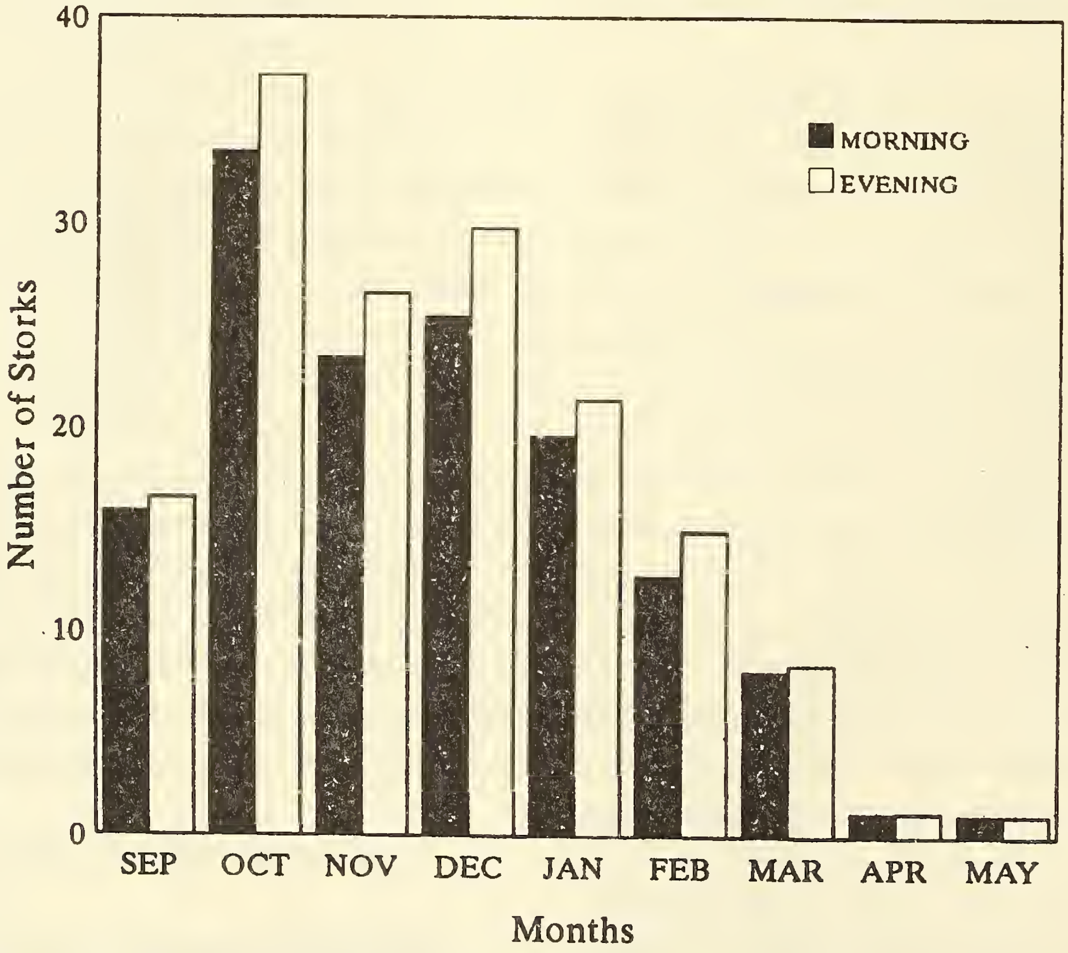


Fig. 1b: Population trend of greater adjutant-stork in North Haibargaon Nesting Colony (1996-97)

breeding season, the stork underwent conspicuous morphological changes to become a brilliantly coloured bird (Plate 1, Fig. 1). The pale whitish wing band of the greater secondary coverts of the non-breeding season became bright silvery white. The upper parts of the body including back, wing, tail and mantle turned to bluish-grey from slaty grey or blackish-grey. The under-tail coverts, which were white at their base and dark smoky grey at the tip, became fluffier. The head and nape became bright red. Black pigment appeared on the pale red part between the head and forehead. The skin of the face and forehead appeared rough and encrusted with dark spots. The base of the bill, just below the dark skin, turned pinkish. The neck turned bright yellow with a pinkish tinge. The dorsal air sac became bright red, encircled by a ruff of white feathers. The gular pouch appeared bright red.

We found that the female was brighter than the male. All breeding pairs wore the breeding plumage except one dull coloured male. There were some storks in the colony which, despite being brilliantly coloured, were smaller than an adult in size, and had a few erect 'hairs' on their head, and black 'hairs' hanging from the tip of the gular pouch. They were most probably younger storks or first time breeders.

As breeding progressed, the breeding pairs gradually regained their non-breeding colour. By mid January, the upper part turned ashy grey; head, neck and forehead became paler from bright red and black respectively. The silvery white wing band also faded. In April, they looked like non-breeding storks with blackish upper parts and a dirty wing band.

(b) Flocking: Breeding storks flocked in the beginning of the breeding season. There were some aggressive interactions, including chasing, fighting, squealing, bill clapping and frequent flying from branch to branch and tree to tree. Flocking occurred due to competition for pair formation and nesting sites. One stork would follow another, and within a short time many storks would gather on a tree. At this time, a stork perched on a branch would stretch its wings, with a forward curve, bend its neck down and bring the open bill between its feet. At the same time, the tail would be cocked and the stork would make a long squeal 'qui-e-e-i', similar to the call of the black kite *Milvus migrans*, or a loud booming nasal sound 'we-i-nh'. The storks were also found to make loud and deep 'woom' sounds like the "lowing of a cow" (Hume and Oates 1890). The female was more vocal than the male, generally squealing and making nasal 'we-i-nh' noises, which gradually became faint later in the breeding season. This high-pitched vocalisation would be accompanied by occasional bill clapping with the bill pointed upward. A dull coloured stork and some subadult storks also visited the colony. However, they did not take part in the flocking.

Flocking would occur on one or two trees in the colony at the same time. Each stork made a small territory of its own and refused entry to other storks, whose approach resulted in ferocious fights. Sometimes flocking (crowding) occurred continuously for ten to fifteen days on a particular tree. These activities started in the morning, gradually declined at noon and again increased towards evening. While some storks formed pairs and selected nesting sites, the remaining moved to other trees for flocking.

These activities increased sharply to a peak in the beginning of the breeding season, and gradually ended in the latter part of the breeding season. While many storks settled down for nesting, some that were unable to find a partner still crowded around to disperse the pairs and invade the nests. We termed these as 'floating storks', most of which were probably first time breeders. Crowding was seen as late as the last week of January.

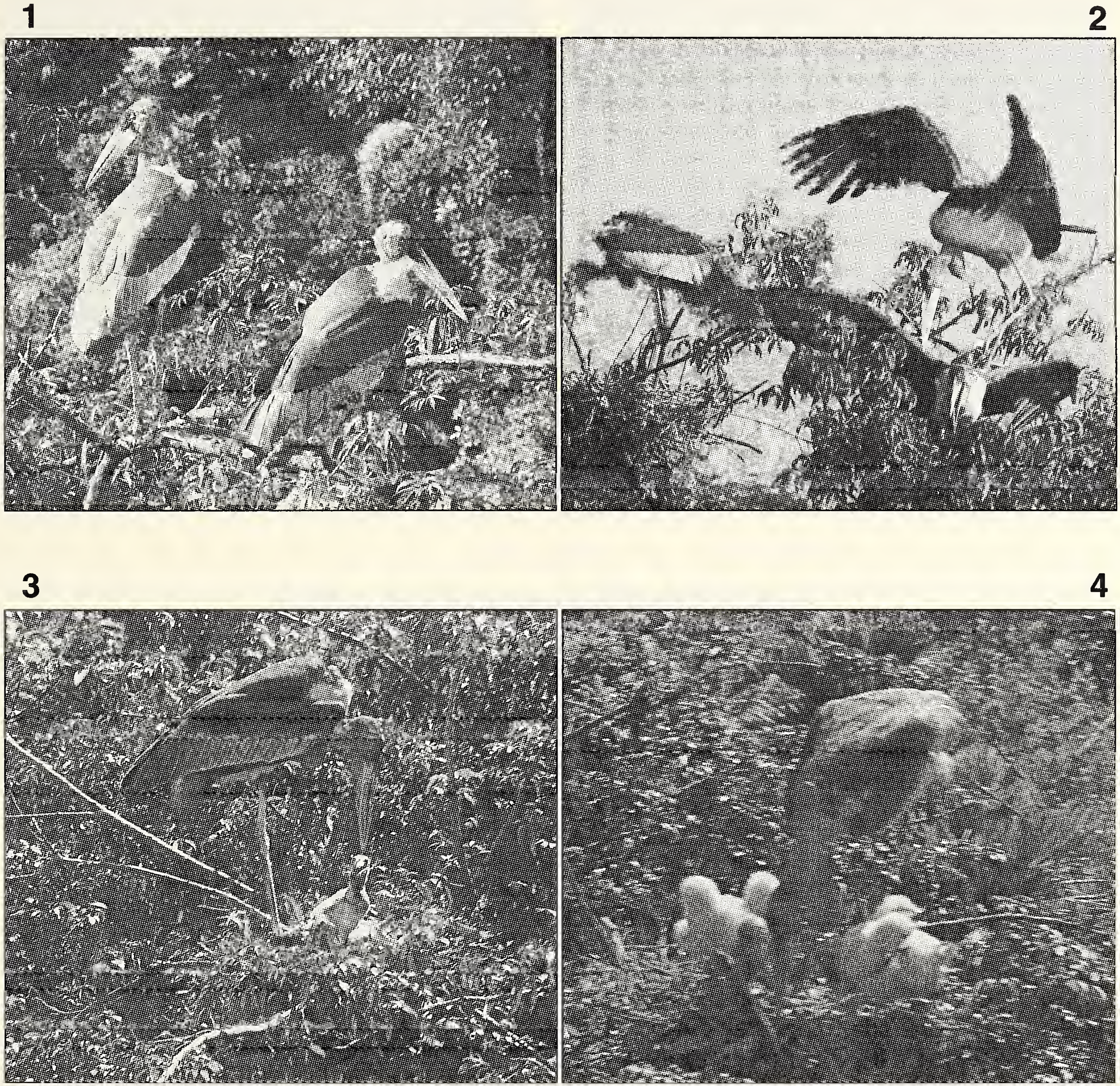
(c) Pair formation and courtship: During the process of crowding, a male stork would create a territory on a potential nest site, and chase other storks that came near him. He announced his territory by frequent, loud bill clattering, pointing the bill upward, downward, or horizontally, and prodded the air with frontal arched body and half folded wings towards its breast. When he accepted a female stork, both perched closely to form a pair. A third stork, usually a female, was often found trying to break the pair bond. The female of the pair was more aggressive than the male in chasing away her rival. In two cases in the first breeding season 1995-96, we found that the third stork temporarily replaced the female of the pair, but was finally driven away. The male easily accepted the new partner.

In some cases, the new pair was found to perch close together continuously for two to three days, without foraging, before building the nest. We saw the pair take initiative in the courtship display, which varied only slightly among different pairs. A male would pluck a fresh twig from a nearby branch and put it near the feet of the female, or drop the twig after holding it for a few minutes. He would touch and gently grasp one of the female's tarsi with his bill. Sometimes the female also touched her own legs. She would withdraw her foot whenever a male grasped it. Once, a male pulled at one of her primaries. He gently clasped her bill, touched her breast in a preening gesture and gradually came closer to her. During this process they leapt to another branch or made a short flight to another tree with the second partner following behind.

When a female approached a male, she would lower her head to touch the male's breast with both her bill and head. He would cross his neck over hers and she adopted a submissive posture. Typical 'swaying twig-grasping' and 'up-down' displays (Kahl 1971, 1972a) were shown by both; however, the former was mostly shown by the male. The stork perched close to its partner bent its neck downward, pointing the bill down about 45°, and oscillated gently from side to side four to five times at half an oscillation per second. Sometimes, at the extreme ends of an oscillation, it would pull or touch a twig and give a mild jerk. Both the partners perched side by side, sometimes preened themselves and showed an up-down display simultaneously or one by one. The bill was then sharply brought down almost touching the breast, or abdomen or feet with a sudden loud nasal 'we-i-nh' immediately followed by throwing it upwards pointing vertically towards the sky. Thus, they clattered their bills, stopping only after the bill was again brought down below the horizontal position. The clattering ceased before the bill was brought to a horizontal position in brief bill-clattering sequences.

(d) Mating and nesting: Usually, the courtship display was followed by mating which occurred on the nest-branch or in the nest. Only twice was mating seen outside the nesting tree. Just before mating, in most cases, both the partners stood side by side in close contact. The male lifted one of his legs onto the back of the female and mounted (Plate 1, Fig. 2). He either mounted from the side, or from the front or rear, standing on her shoulder for a few seconds and then positioning himself for copulation. As soon as the male mounted, the female bent her 'knees' in a submissive posture, both the wings spread for balancing. During copulation, the male flapped his wings vigorously and sometimes snapped his bill frequently. The bill clattering usually started as soon as he copulated, at times simultaneously with mounting. On a few occasions, the sound of the bill clapping was not heard. During copulation, the female lowered her open bill 45°, swayed it from side to side and made a moaning sound. The male usually clasped the female's bill and clattered against her bill. After copulation, he stood on her shoulder for some time. Mating was sometimes followed by preening.

The whole process of mating ranged from 11 to 68 seconds (average 25.56 ±10.38 sec, n = 52). Mating occurred 1-6 times a day, between 0545 and 1635 hrs. Out of 141 matings observed, Singha, Hillaljyoti *et al.*: *Leptoptilos dubius* PLATE 1



Figs 1-4: Greater adjutant-stork *Leptoptilos dubius*: 1. Adults in breeding plumage, 2. Adult male mounting on a female, 3. Parent tending one week old chick, 4. Adult feeding two week old chicks

Singha, Hillaljyoti *et al.*: *Leptoptilos dubius* PLATE 2

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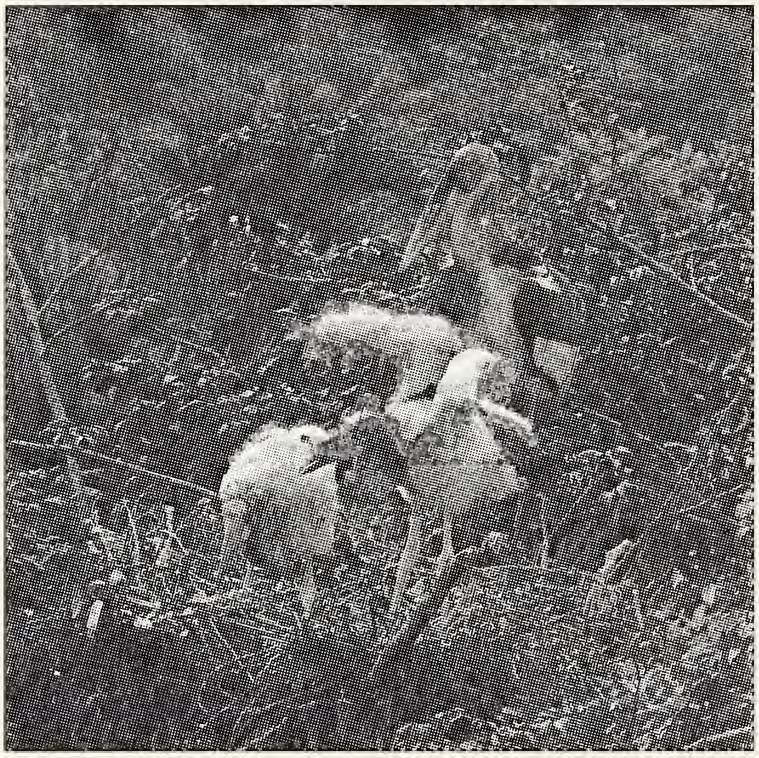

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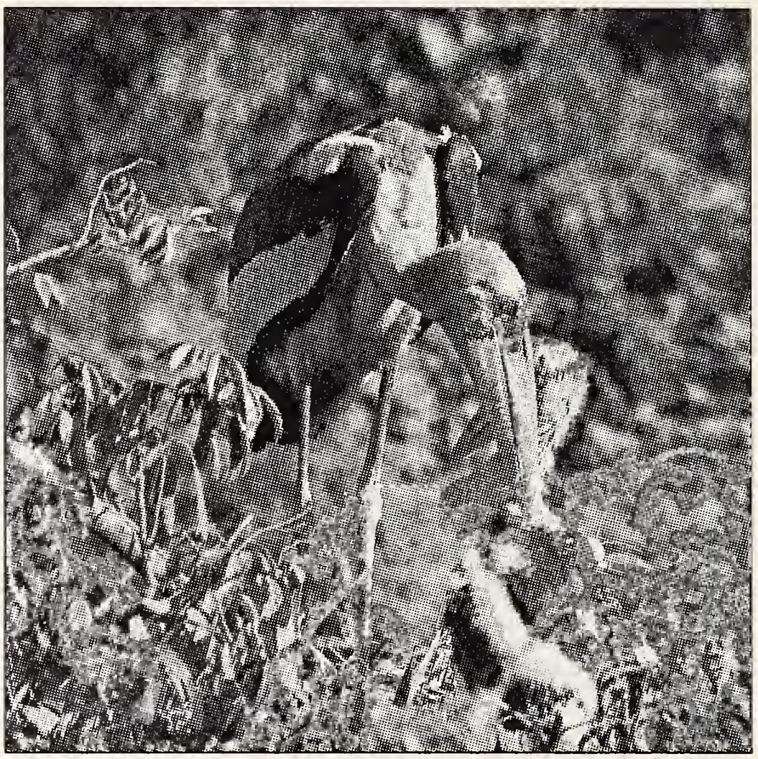

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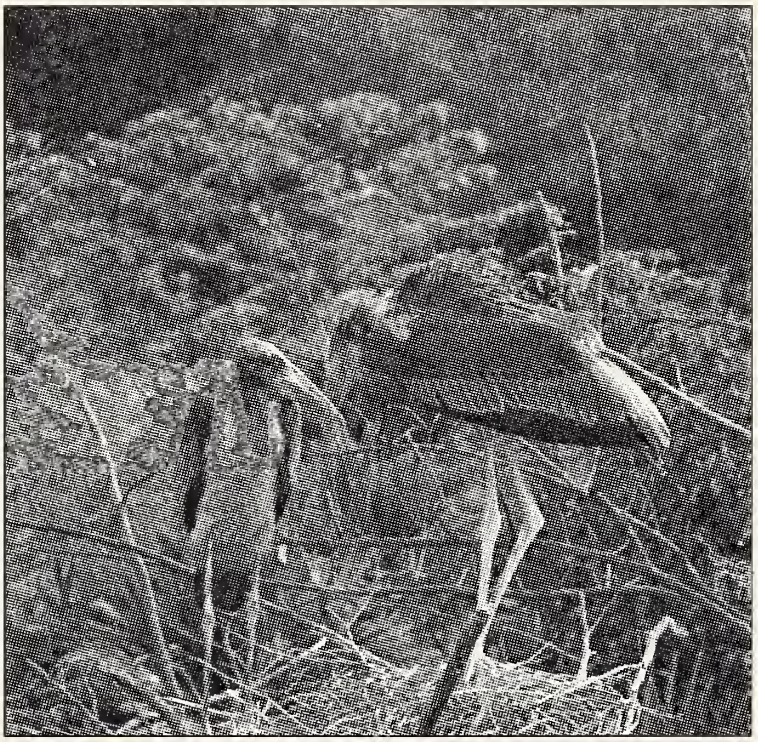

Figs 5-7: Greater adjutant-stork *Leptoptilos dubius*: 5. Parent with four week old chick, 6. Parent tending six week old chick, 7. Nine week old juvenile

81 (57.45%) occurred in the forenoon, and 59 (41.84%) in the afternoon. One was seen at mid-day. Mating was more frequent during nest building and early incubation. However, late mating was seen in four pairs whose first chick was 26, 32, 43 and 45 days old, respectively.

Simultaneously with mating, nest construction began. The male would place a green leafy twig on a flat horizontal branch, with or without an erect limb. The female stepped on it to hold it down, and soon the base was formed by piling one twig upon another. During the initial stages of nest construction, the female stood guard at the nest, while the male brought most of the nest material from the same or other trees in the colony. The stork did not go beyond 200 m to bring nest materials. Usually, mating occurred after frequent nest material trips by the male. During nest building, the female became more vocal, making a loud booming sound, accompanied by bill snapping. The male responded by clattering his bill when he reached the nest. Both sexes arranged the nest material. They would remove leaves from the nest and drop them as if cleaning the nest. In the early stages of nest building, the male generally roosted with his partner in the nest or near the nest. The nest construction took 2 to 4 days. Soon after that, the female spent more time on the nest, until she laid the eggs. Then the male took care of the nest, relieving the female for longer periods.

During nest construction, the male and female never left the nest together, but on two occasions the storks were absent from the nest (11 and 36 minutes) to collect nest material.

Incubation: The eggs were laid asynchronously and the incubation started as soon as the first egg was laid. The newly laid eggs were chalky white, with a green and blue tinge, which became soiled as the incubation proceeded. Both male and female incubated. During incubation (34.6 ±2.70 s.d. days, n = 5), the incubating stork preens, flaps and stretches its wings, it rearranges and repairs the nest, rotates the egg(s) and protects the nest from other storks and birds. When the bird stands up after a long bout of incubation, it shakes its body, stretches its neck forward with an open bill slightly downwards and changes its orientation for the next phase of incubation. It rotates the eggs to different positions by grasping them with the bill or shovelling them towards its feet with the tip of the beak. It then tilts the nest slightly with its feet, and the eggs roll back to the depression in the middle of the nest.

Post-hatching period: a) Growth of chicks and associated behaviour of parents: The growth rate of the chick varied in different nests. A general pattern of growth and behaviour of the chick is described below.

The chicks hatch at intervals of one or two days. The newly born chick is about 10 cm tall, and has a pale yellow, slightly curved down beak and a large blackish head, and neck with yellow patches. Dorsally, the body has bluish-black down feathers, and pink underparts. The eyes are large and black; the swollen eyelids are blackish, while the forehead is sky blue. The chick grows fast and becomes double its size within a week, with white down feathers almost covering the back. During the first week of their life, the chicks spend most of the time sleeping.

When a chick hatched, the parents stood with legs apart and tended the baby frequently. The behaviour and posture of the parent indicated egg hatching (Plate 1, Fig. 3). The chick made feeble sounds, which became louder with time, into chittering. Both parents fed the young. The parents regurgitated food on the floor of the nest and the chicks picked it up. Soon after hatching, the parents started regurgitating black, granular half-digested food matter, so that the hatchlings could feed easily. The feeding frequency by regurgitation was higher in the early stages. Initially, the chicks could not consume all the food brought to them; the excess was re-ingested by the parent, and regurgitated later. While re-ingesting, the parent pressed large portions of food between its mandibles to soften and crush it, so that the chicks could devour it easily. We found that although the parents would not feed the young bill to bill, it would help by holding the food such that it could be easily swallowed. The chick would jerk the food, toss its head forward and backward quickly and swallow the food. The chicks were found to be voracious feeders right from hatching. Even a day old chick tried to swallow a frog, much larger than its head! In one case, a three-day old chick gulped a fish that was larger than its body length; for some time the tail of the fish protruded outside its bill.

At two weeks (Plate 1, Fig. 4), the white down feathers completely covered the body of the chick, however, the underparts were still pinkish. The yellow patches on the head almost disappeared. The eyelids became whitish. The forehead or shield turned white with black spots. Dark black pigment spreads over the cheek. The ventral side of the throat was covered with dark black pigment in longitudinal bands. Dorsally, the neck was greyish and the shoulders black. Erect grey and white 'hairs' grow on the head and neck. The ill-developed sky-blue pouch could be distinguished. Beneath the wings and near the flanks, black feathers developed. The legs and toes became pinkish in colour.

Generally the parents relieved each other after more than 24 hrs. The reliever brought food for the chick(s) once a day. For about two weeks, most of the parents' time was spent in brooding the chicks and after that, in standing guard. However, in the morning and evening, and during rain they brooded and sometimes shaded the youngs. The parents also provided shade to the chick(s) by stretching their wings and standing against the sun.

The 3-week old chick is covered all over with snow white foamy down feathers, except ventrally. The bill is pale yellow with black marks at the base. Black 'hairs' hang from the tip of the pouch and on the shoulder. Pupils black, iris brown. Legs pinkish-white.

The 4-week old chick is about 30 cm in height. The shield is still white with black spots. The grey and black crest of thick 'hairs' grows longer. Down the throat, and ventrally, longitudinal black patches are prominent. Black primaries and secondaries start to grow. Black tail feathers also appear.

At 4 weeks, a chick can stand on its feet and flap its wings 4-5 times at a stretch (Plate 2, Fig. 5). The wing span is approximately 60 cm. The chick walks in the nest. The parents also gradually start leaving the nest, initially for short durations only. When the parents return with food, the young ones perform typical begging displays. They drop down to their tarsi opposite each other (if more than one young), wings half folded, slightly lifted upward, body bent forward, tail cocked and toss their heads up and down rhythmically with open bill and nasal 'honk-honk' sound.

In the 5-week old chick, the primary feathers of the wings start developing. Initially they have a black tip and bluish rachis. The primaries at the tip of the wings are now larger, about one and half inches. The tail feathers become more prominent. The pinkish white legs turn whitish. The longitudinal black patches of the throat become concentrated only on the pouch. The ear opening is surrounded by a white mark. At this stage, a chick tries to leap in the air, frequently flapping its wings. It defecates over the edge of the nest and swallows food very fast.

A 6-week old chick is fully covered by thick down, which has changed from snowy white to dirty white (Plate 2, Fig. 6). The black spots on the shield are almost gone. The sky blue throat pouch, with pink tinge at the base, and sparse black pigments, becomes elongated. The black 'hairs' hanging from the pouch become longer. Black feathers on the shoulder around either side of the base of the neck turn brownish and grow to meet at the breast, forming a necklace-like band. The wings develop four layers of feathers: the lowermost black primaries are concealed by a broad brownish band of greater secondary coverts, and two more black layers above the second layer. Twelve broom-shaped fan feathers with blue rachises grow at the tail, black horse-shoe shaped flat feathers at the tip, followed by thin grey 'hairs' hanging from it.

At this stage, the parents even stay away from the nest at night as the chick is able to defend itself. It would even threaten a crow or a kite hovering overhead by poking its head towards the intruder, with a harsh 'khll-o-ck' sound. When other storks came near the nest, it sat down on its tarsi, faced the intruder with half folded wings, and tossed its head up and down, emitting a nasal 'khll-i-ck khll-i-ck' sound rhythmically with movement of the head till the intruder flew off. At this stage, the chicks also clean the nest like adults.

By 7 weeks, another row of black feathers developed just above the fourth layer on the wings. Two longitudinal rows of black feathers were growing on either side of the midline of the mantle. When the wings were folded, three-fourths of the upper part was covered by black feathers. At this stage, the parents came to the nest only to feed the chick(s). The chick flapped its wings more frequently, 10 to 12 times at a stretch.

At 8 weeks, six rows of black feathers appeared on the wing. The tail fan became elongated and expanded. While flapping the wings, the chick tried to lift itself up in the air.

Throughout the fledgling period, the parents occasionally nursed the chick. Up to 3 weeks, they would gently touch the head and body of the chick, but later they also preened the chick.

(b) Growth of Juvenile and associated parental behaviour: At nine weeks, the chick attained juvenile stage (Plate 2, Fig. 7). It almost equalled its mother's height. The upper parts became completely black. The broad brown layer of the secondary coverts became more distinct. The shield was white with very few black spots. The bill was pale yellow. The ear opening surrounded by white mark became more prominent. The pupil was black and the iris brown. Near the eyes and on the cheek, black spots were sporadically present. The thick crest of black and grey 'hairs' on the crown and neck were longer, and so were the 'hairs' at the tip of the whitish pouch. The legs became creamish-white.

The juvenile's food was supplemented with pieces of meat and intestinal parts of mammals in addition to fish, amphibians, reptiles and birds. Gradually, it can leap straight upward 1-2 m in the air with vigorous flapping of wings. This leaping is more frequent when the wind blows. At about four months, the juvenile flies from one branch to another and then to the other trees in the colony. It can chase other intruders from its nest. Sometimes it flies outside the colony and comes back to the nest to be fed by the parents. It can also be seen on other nests in search of food and nest material. The parents feed the juvenile till it fledges. The fledging period was about 142 days (141.94 ±22.45 days, n=35). The first flight of the juvenile was seen at 126.25 ±9.35 s.d. days (n=12). The fledging period ranged from 96 to 173 days in the first breeding season, and 110 to 197 days in the second breeding season in different nests. The juvenile fledged asynchronously; not necessarily the older sibling leaving earlier.

Other Breeding Behaviour: Greeting display: Greeting display between a pair commences soon after pair formation. It gradually declines by the time the chicks reach juvenile stage, because the parents hardly come to the nest at the same time. Among the greeting display, the up-down display and bill clattering were common. Usually when a partner arrives at the nest, the other partner greets it by upward bill clattering. Then both demonstrate an up-down display. Each stork could recognise its partner from a long distance; even about 100 m. When nest material was brought by the male, he generally uttered a low pitched 'kis-kis' sound with one second pause after each 'kis'. The female brought nest material with nasal 'we-i-nh we-i-nh' sound. In the early part of the breeding season, a female greets the male with her long typical squeal, swaying the bill from side to side. When a female arrives on the nest, the male sways his bill from side to side, bowing down his head with a typical 'kis-kis' sound. When a male reaches the nest, the female sways her down-pointed bill from side to side, and places the nest sticks in accordance with the movement of the bill. Downward short duration bill clattering was also observed to greet each other. Sometimes there was no greeting display.

Aggression: Agonistic behaviour was seen more in the beginning of the breeding season. Aggressiveness also varied according to the individual and the situation. Generally, the female appeared to be more aggressive. Storks were found to chase other storks, which approached their nest, sometimes leaving behind an unprotected nest with egg(s) or chick(s). A stork could chase another stork up to 100 m, flying at it with a stretched neck and loudly snapping bill. Loud bill clattering was not only a greeting display, but also a threat to the other storks. Sometimes a breeding stork was found to tolerate the presence of other storks and even crows very near its nest.

In the early part of the breeding season, during nest building, and even during incubation, some storks try to invade other nests for occupation or to replace a partner from an established pair. A case of nest invasion occurred in the first breeding season when one pair occupied the nest of another pair. Once a stork was also found to snatch food from another stork's nest. While fighting they poked their bills at each other's head in quick succession. Post flying juveniles were also found to be aggressive towards other adult storks that tried to enter their nest.

Nest arrangement: Storks repaired and cleaned their nest throughout the breeding period, but this activity progressively decreased as the young grew up. The storks cleaned the nest by removing egg shells and decomposed old leaves from the interior of the nest. They frequently picked up leaves by inserting one third of the bill into the huge nest and threw rotten leaves outside the nest. They grasped sticks and placed them, pulling and pushing them all along the nest rim and also at the bottom. Standing on one leg at the centre of the nest, the bird slowly placed the sticks along the periphery, so that a shallow depression developed at the centre of the nest. Sometimes this would continue for more than half an hour.

Nest material stealing: On finding an unguarded or vacated nest, storks stole nest materials. Even a five-month old juvenile was seen stealing sticks from empty nests. Sometimes they would rob nest material in the presence of its owner.

Father-offspring mating: What appeared to be father-offspring mating was seen in one nest in both the breeding seasons. The adult male suddenly placed one leg on the back of one of his young and mounted it. He stood on the back for 12 to 20 seconds and came down. Sometimes he appeared to copulate with the young, with or without mild bill clattering. The young uttered harsh chittering. In the first breeding season, this was observed ten times when the young were 9 to 11 weeks old. In the second breeding season, it was observed twice when the young ones were 5 and 9 weeks old.

DISCUSSION

Chronology: The greater adjutant-storks arrive at the North Haibargaon breeding colony just after the monsoon, when the dry season begins. In both the breeding seasons, the time of arrival was identical suggesting that the storks follow a definite time frame for breeding. The nesting period synchronises with the reducing water level in the lakes and ponds (Saikia and Bhattacharjee 1996a, Bhattacharjee and Saikia 1996). All other breeding storks in India, painted stork *Mycteria leucocephala*, white-necked stork *Ciconia episcopus*, black-necked stork *Ephippiorhynchus asiaticus*, Asian openbill stork *Anastomus oscitans* and lesser adjutant-stork *Leptoptilos javanicus* breed just after monsoon (Ali 1996). In Assam, from September onwards water level gradually recedes with the decreasing rainfall. This period also coincides with the increase in availability of prey species, as many species of fish and frog breed during monsoon in the inundated low-lying areas. When water level drops, they concentrate in drying pools and puddles and become easy prey for the stork.

Most bird species breed around the time when food supplies are readily available (Thompson 1950). In the congeneric Marabou stork *Leptoptilos crumeniferus*, breeding usually begins in dry season and ends in rain (Brown *et al.* 1982). Pomeroy (1978b) also states the possibility of an intrinsic (circannual) rhythm for nesting period in the Marabou stork. The American wood stork *Mycteria americana* initiates nesting when water level goes down (Kahl 1964). Seasonal rains strongly influences the beginning of nesting in the Maguari stork *Ciconia maguari* (Thomas 1985). It seems that food supply and seasonal change with shorter days correspond to initiate breeding of the greater adjutant-stork in North Haibargaon breeding colony.

The population trend throughout the breeding season in both years of our study suggests that as the breeding season progresses, the greater adjutant-storks start leaving the colony. The storks that did not build nests leave the colony; the parent storks also spend less time in the colony when the young grow up. In the second breeding season it was seen that the number of storks reached a peak in October (Fig. 1b) when almost all breeding storks had arrived in the colony. In both the seasons there was a small population peak in December (Figs 1a & b). This could be due to the late breeders who returned to the colony. A similar second small peak was seen in a painted stork colony by Urfi (1993), which he speculated could be due to a second breeding attempt or prolonged breeding effort. In Maguari stork also, late-arriving individuals begin to build nests well after the beginning of the breeding season (Thomas 1986).

The reason for smaller numbers of storks in the morning count is probably because some storks leave very early for foraging, much before sunrise. In the evening, all the storks returned to roost, so more birds were seen.

General Breeding Biology

External morphological changes: The external morphological changes in the greater adjutant-stork during the breeding season were similar to the observation of Saikia and Bhattacharjee (1996a) and, Bhattacharjee and Saikia (1996). Similar changes occur in the Marabou stork also (Brown *et al.* 1982). Pomeroy (1977b) found that males of the Marabou stork were considerably larger than females, which we found in greater adjutant-stork also. Kahl (1972a) has reported this earlier. In painted stork (Desai *et al.* 1977) and American wood stork *Mycteria americana* (Kahl 1962), males are larger than females. The brighter coloured female approaches the male to initiate courtship. Competition for pair formation was between females for the male who had selected a potential nest site.

Flocking and aggressive behaviour: Lack (1968) also observed that in some colonial species, the sub-adults also come to the breeding sites, form pairs, occupy nesting sites and build nests, but do not proceed further. We found some sub-adults and some probable fresh adults arriving in the colony. Bhattacharjee and Saikia (1996) also observed that both sub-adults and non-breeding greater adjutant-stork also came to the nesting colony, but Pomeroy (1977a) observed that it does not necessarily follow that all storks in breeding plumage are sexually mature. The minimum age at first breeding is 4 years in Marabou stork (Pomeroy 1977b), and 3 years in male and 4 years in female in Maguari stork (Thomas 1984). According to Bhattacharjee and Saikia (1996), the greater and lesser adjutant-stork become sexually mature at 3-4 years. Lack (1968) has explained the arrival of the sub-adults at the breeding colony as the preparatory year to learn the best feeding areas around their nest without the strain of finding food for a brood.

Bhattacharjee and Saikia (1996) reported rigorous vocalization and 14 to 16 storks flying together from tree to tree in the early part of the breeding (September), what we have called 'flocking'. Coulter (1989) has termed the aggressive interactions in American wood stork as 'mobbings' and Kahl (1972b) has referred to them as "bachelor parties". Although aggression was always associated with crowding, fight was not between two storks; instead a flock of five to fifteen greater adjutant-storks took part together in this activity. The aggressive interactions of 'mobbings' in American wood storks were moderately frequent in the early part of the breeding season, and rose to a peak in the following weeks correlating with an increase in nest building, and declined gradually (Coulter 1989). We observed the same in the greater adjutant-stork.

We observed that in greater adjutant-storks aggressiveness varied individually, and female storks seemed to be more aggressive. While Thomas (1986) noted that attacking Maguari storks were mostly males. Though female American wood storks are generally less able to defend themselves (Coulter 1989), we found that greater adjutant-stork females even invaded other nests. As Coulter (1989) recorded nest invasion in American wood stork, we found a similar case in greater adjutant-storks too. The replacement of one incubating female American wood stork by another pair and throwing out the former's egg was observed in greater adjutant-storks also, but in the case of greater adjutant-storks the aggressor was a female. Moreover, while guarding a nest with eggs or chicks, a female sometimes chased away others near the nest, leaving the nest unguarded. Such behaviour was not seen in American wood storks by Coulter (1989) who found that unguarded chicks were thrown out by neighbouring storks. Similarly, in greater adjutant-storks, while pulling nest sticks from an unattended nest, the "robber" stork attacked the defending chicks, of which, two 3-week old chicks fell out.

The 'aerial clattering threat' described by Kahl (1972a) was also observed in the greater adjutant-stork. According to him, lesser adjutant remains silent while chasing another stork in the air, but Marabou clatters loudly as the opponent is approached closely. Similar behaviour was observed in the greater adjutant-stork.

The other hostile display described by Kahl (1972a) such as snap display, pre-flight snap, erect-gape and anxiety stretch were noticed in the greater adjutant-stork. However, forward poking, which is similar to 'forward display' behaviour in herons (Meyerriecks 1960; Tomlinson 1976), was not mentioned by him. In this behaviour, two greater adjutant-storks stand erect on their nest or branch face to face and poke at each other, sometimes with a bill snapping sound, frequently but hardly any physical contact. Sometimes a greater adjutant-stork was also seen shooting its bill sharply in horizontal direction in the air when the opponent was at a distance.

Pair-formation, courtship and greeting display, mating and nesting: In many aspects of morphology and behaviour, the greater adjutant resembles its African cousin, the Marabou stork (Kahl 1974), but it is closer to the lesser adjutant (Kahl 1970). We saw the same 'swaying twig-grasping' as described by Kahl (1972a) for the greater adjutant and Marabou stork. For the first time we observed side to side swaying of the bill by a male greater adjutant to greet a female partner at her arrival to the nest with "kis-kis" sound. This behaviour can be compared with the 'advertising sway' of the Asian openbill stork described by Kahl (1971). The differences are; (a) greater adjutant-stork did not lift its feet with each oscillation; and (b) greater adjutant-stork makes a typical sound. The female greater adjutant also greeted the male in the nest by swaying downward pointing bill and arranging nest sticks. Similar 'twig passing display' is seen in the great white egret *Egretta alba* (Tomlinson 1976), where the female greets the male on his arrival to the nest by 'stretch display'.

The most common greeting display in the greater adjutant-stork is the up-down display that Kahl (1971) has seen in all except the Saddlebill stork. He has mentioned that all the three species of *Leptoptilos* give frequent up-downs whenever a member of a pair returns to the nest. But we found that the greater adjutant did not give an 'up-down' display every time its partner arrived at the nest.

Kahl (1970, 1971, 1972a and 1974) emphasised on the difference between Marabou storks and both the adjutants in up-down display. In the former, the bill is first thrown upwards and vocalizations are made, then the bill is pointed downwards and clattered. In the latter the bill is directed upward during both vocalizations and clattering. We also observed the upward bill clattering, but would like to stress that the clattering did not always cease before the bill reached horizontal position; sometimes clattering stopped only after the bill pointed downwards. On some occasions we observed one member of the pair greeting the other by short downward bill clatterings. Vocalization of the lesser adjutant is hoarser and more rasping than the greater adjutant (Kahl 1970).

There is no literature regarding the mating behaviour of greater adjutant-storks. However, it was found that the loud copulation clattering of greater adjutant-storks resembles that of other storks, except Asian openbill storks where the male does not clatter his mandibles loudly (Kahl 1970). The balancing posture of the female during copulation is similar to that of other storks except the white stork where the female does not spread her wings wide (Kahl 1971) and the Jabiru stork where the female usually opens her wings fully at first and then closes them partially after the male is in position (Kahl 1973). The occasional post copulation preening in greater adjutant-storks is also found in other storks, e.g. painted storks (Desai *et al.* 1977) and Maguari stork (Thomas 1986). The copulation duration of greater adjutant-storks (25.56 ±10.38 sec) is found to be the longest among storks: 10 sec in painted stork (Desai *et al.* 1977), 8.77 ±1.15 sec in Maguari stork (Thomas 1986), 24 sec in black-necked stork and 15 sec in Jabiru stork (Kahl 1973). Late mating, as we found in greater adjutant-storks, is also reported in painted storks where copulation occurred even after the fledging of the young (Desai *et al.* 1977). However, attempted father-offspring mating behaviour is not reported in other storks. It was, however, not known if the young was a male or female.

Development – egg to fledgling: Our description of freshly laid eggs of greater adjutant-storks is similar to what was described by Hume and Oates (1890). The asynchronous laying of eggs is also reported by Saikia and Bhattacharjee (1996a). Lack (1968) states that in Ciconiiformes, the successive eggs in a clutch are laid two or more days apart, incubation starts with the first egg, and the young hatch one or more days apart.

The development of the chick to fledgling stage and associated parental behaviour are more or less similar with other storks. The stork nestlings spend most of their time between meals sleeping and thereby reduce energy demands

(Kahl 1962). The rapid early growth pattern exhibited by altricial birds, aids to survival in several ways. A four-week old greater adjutant tried to leap in the air with flapping wings. The Marabou chick can stand and flap wings in 17 days (Brown *et al.* 1982) and Maguari chick can stand in 22 days (Thomas 1984). The postures, movements, and vocalizations in the begging display and nesting defence display of both Adjutant species were quite similar to the Marabou stork (Kahl 1972a). However, in solitary breeding storks, vocalization of the chicks are not as loud as those in colonial species (Kahl 1973).

Incubation and Fledging Period: Pomeroy (1978a) estimated the age of the young " fairly accurately" from their appearance to get the date of hatching, but our observations on different nests indicated that it would definitely vary. We found that individual chick growth was quite varied, i.e., a particular stage could not be always assigned to a particular age. Some chicks grew faster than the others.

The incubation period of the greater adjutant is around 35 days as observed in the five focal nests. Except for the five nests, prolonged incubation period exceeding 35 days was noticed in some other nests. In one case, even when the first chick had grown to 30 days, an egg was still being incubated. Finally, it was dropped from the nest. Prolonged incubation has been reported in a number of bird species (Skutch 1962, Afik and Ward 1989). Drent (1975) suggested that prolonged incubation was a functional response caused by the inherent variability in incubation period. Marks (1983) thinks that prolonged incubation behaviour is related to the time interval in which the entire clutch would normally hatch. This does not seem to be the case in greater adjutants whose clutch size is small and eggs hatch simultaneously. Prolonged incubation is also reported in painted stork (Desai *et al.* 977). Pomeroy (1978a) reports that one pair of Marabous' incubated for 150 days, and eventually one young fledged from that nest. He regarded it as re-laying of eggs in the same nest, which he found was 8% in Marabou stork. We also found 7.5% cases of probable re-laying in greater adjutant-storks. In three nests, we also noted a prolonged incubation period of 93, 97 and 107 days, which we suspect was re-laying.

According to Lack (1968), the incubation period in Ciconiidae varies between 30-33 days. Incubation period in greater adjutants reported earlier is 30 days (Saikia and Bhattacharjee 1996b). It seems that our estimate of incubation period of 35 days is longer than in other storks: 32 days in American wood stork (Heinzman and Heinzman 1965), 32 days in white stork (Schuz 1972), 29-32 days in Maguari stork (Thomas 1984, 1986), 32 days in painted stork (Desai *et al.* 1977), 30-31 days in white-necked stork (Scott 1975), 28-30 days in Abdim's stork *Ciconia abdimii* (Farnell and Shannon 1987) and 29-31 days in Marabou stork (Brown *et al.* 1982, Kahl 1966, Pomeroy 1978a).

The fledging period of greater adjutant-storks was about 142 days. The fledging period in Marabou stork was 132-135 days (Kahl 1966, Pomeroy 1978a). There was a gap of 67-74 days between first and last fledging in the greater adjutant-stork colony. We also found that young which hatched earlier did not necessarily fledge earlier. Even siblings of the same nest fledged asynchronously. However, we could not find out the exact fledging period according to the first flight of the nestling, as it was impossible to monitor all the nests of the colony continuously. However, we were able to calculate the duration of hatching to first flight in a few nests (*c.* 120 days, n=12) which was closer to the fledging period in Marabou stork.

Comparing its biology with other storks, it appears that the greater adjutant-stork resembles, in most of its behaviour and biology, its congeneric the Marabou stork. The long breeding season of this colonial bird is an important phase in its life cycle, during which the crucial need seems to be food.

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CURRENT STATUS OF THE GANGES RIVER DOLPHIN, *PLATANISTA GANGETICA* IN THE RIVERS KOSI AND SON, BIHAR, INDIA[1]

(*With one text-figure*)

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Key words: *Platanista gangetica*, population, threats, conservation, River Kosi, River Son, Bihar

Surveys were conducted in February and March, 2001 to assess the current status of the Ganges river dolphin in the Rivers Son and the Kosi. No dolphin was sighted in the entire stretch of about 300 km of the Son, in Bihar. The local fishermen reported total elimination of dolphin population in *c.* 100 km stretch of the Son from the Uttar Pradesh - Bihar border to the Son Barrage at Indrapuri. During monsoon, the dolphins migrate for about 200 km from the mainstem of the Ganges into the Son up to the barrage. Dolphins were sighted in the entire stretch of about 300 km of Kosi between the Kosi Barrage at the Indo-Nepal border and its mouth at Kursela in Bihar. A total of 87 dolphins were sighted in the Kosi during the survey, however, many must have been missed due to the highly braided channel of the river. In both the rivers, no apparent source of pollution was found. Siltation and construction of the barrage were observed to be the main cause of habitat degradation in both the rivers.

INTRODUCTION

The Ganges river dolphin *Platanista gangetica*, commonly known as *susu*, is distributed in the Ganga-Brahmaputra-Meghna and Karnaphuli-Sangu river systems of India, Nepal and Bangladesh, between the foothills of the Himalaya and the estuarine zone.

All the three Asian species of freshwater dolphins are classified as Endangered or Critically Endangered. Listed in order of most to least threatened, are *baiji* (*Lipotes vexillifer*) in River Yangtze of China (population: a few tens), *bhulan* (*Platanista minor*) in River Indus of Pakistan (population: a few hundreds), and *susu* (*Platanista gangetica*), population about 2,500. The fourth freshwater species, *boto* (*Inia geoffrensis*) is found in the Amazon River System in South America, population of which is estimated to be about 5,000. These four are the only freshwater dolphin species found in the world. Obligate river dolphins live only in fresh water, their physiological and ecological requirements apparently make it impossible for them to live in marine waters.

Other small cetaceans are normally associated with the marine environment, but they do range far upstream in large Asian rivers. These include, the finless porpoise (*Neophocaena phocaenoides*) in the Yangtze river of China, and Irrawaddy river dolphin *Orcaella brevirostris* in the Ayeyarwady (formerly Irrawaddy) river of Myanmar, Mahakam river of Indonesia, and Mekong River of Lao P.D.R., Cambodia, and Vietnam. *Sotalia fluviatilis* is another such species found in the Amazon-Orinoco river systems of South America.

The freshwater dolphins have a longer snout than marine species, which probably help them in collecting their food in the mud bottom of rivers. The two species of genus *Platanista* found in the Ganga and Indus system are practically blind, as they have eyes without crystalline lenses (Herald *et al.* 1969) and the

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transparency of their cornea is limited as it is vascularised (Dawson 1980). While visual acuity is reduced in these species, they may be able to form crude images using the narrow aperture of the pupil in a manner analogous to a pinhole camera. Amazon and Yangtze river dolphins have very limited vision.

Evolutionary adaptation to a fluviatile environment has resulted in a regression of the eye and the development of a sophisticated echolocation system, which allows Odontocetes, the suborder of toothed whales, to 'see' their environment through sound. Pulsed vocalization produced in specialized air sinuses in the nasal passages is focused by the 'melon' (forehead), which functions as an acoustic lens. The reflected pulsed sounds are received back through the jawbone, transmitted to the middle ear, and then analysed by the comparatively large brain.

Although the meta-population of the *susu* totals over two thousand, isolated subpopulations, especially in Nepal and in the Karnaphuli-Sangu River System of Bangladesh, have become extinct or critically reduced by the barrier effects of dams and barrages (Haque 1976, Smith *et al.* 1994). The distribution range of *susu* is shrinking, as evinced by their elimination from many of the smaller tributaries and upper reaches of the Ganga, where they were found earlier. Their population in the mainstem of the larger rivers is declining as they are being killed both incidentally as well as directly. Also, they compete unsuccessfully with humans for shrinking water and prey resources. The IUCN recently changed the status of the species from Vulnerable to Endangered (Baillie and Groombridge 1996).

Dolphins swim almost constantly on their side. Shortly after a dive, they spin 90° on their lateral axis and 180° on their longitudinal axis, to swim on their side in the direction opposite to their surfacing direction. The head sweeps up and down in a scanning motion and the deeper pectoral fin, or flipper, trails along or slightly above the bottom. The flippers are thought to have an important tactile function. Shortly before surfacing, the dolphins reverse the spin back to the direction in which the dive began.

In the Karnali river of Nepal, in their far upstream range as well as in the mainstem of the Ganga, *susu* are found most often in 'primary habitats' where convergent streams create an eddy counter-current system in the mainstream flow (Smith 1993). Less often, the dolphins are found in "marginal habitats" where the river meanders and creates similar eddy counter-current systems, which are also areas of high human use, making them particularly vulnerable to local environmental disturbances.

The river dolphin often takes advantage of the ecotone created by the transition between scour pools and running waters, visible as eddy turbulence. They prey on species migrating along the mainstem, while monitoring foraging opportunities from within the hydraulic refuge of counter-currents.

Current Status of the Ganges river dolphin

The total population of the *susu* was roughly estimated to be only 4,000-5,000 (Jones 1982). Dolphins are sighted throughout the Ganga from the Middle Ganga Barrage, Bijnor (129 km downstream of Haridwar) to its mouth at Sagar Island in the Bay of Bengal. About 35 *susus* have been isolated between the two barrages at Bijnor and Narora (166 km) in Uttar Pradesh (Sinha *et al.* 2000). The population between Narora and Allahabad (about 500 km) in low water season (January-March) is very sparse (a few tens) (Sinha 1999). In the lower reaches of the Ganga in West Bengal, only 152 *susus* were sighted in the Bhagirathi-Hooghly river system below Farakka Barrage (Sinha 1997). Maximum dolphins survive in the Ganga mainstem between Allahabad and Farakka. Less than 100 have been estimated in Chambal river, a tributary of the Yamuna. A total of about 2,000 dolphins have been estimated in the Ganga-Brahmaputra river systems in the Indian territory (Sinha 1999). A few hundreds are present in Bangladesh. A comprehensive review of the *susu's* status in the entire Ganga system including tributaries has recently been documented (Sinha *et al.* 2000).

In the nineteenth century, dolphins were plentiful in the entire distribution range, though no actual data on populations is available. They were found in the Yamuna as far as Delhi, even in May when water was very low (Anderson 1879). In the last couple of decades, no dolphin has been sighted in the Yamuna at Delhi. Their current distribution in the Yamuna is mainly below the confluence of the Chambal and Yamuna near Etawah. In most of the small tributaries, dolphins have become locally extinct or are sighted only in the rainy season.

Platanista gangetica is legally protected, being included in Schedule I of the Indian Wildlife Protection Act (1972) and in Appendix I of Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES), which prohibits trade in dolphin products by signatory countries.

Past Distribution in Bihar

Anderson (1879) has mapped the distribution of dolphins in the entire stretch of the Ganga, all its tributaries both large and small, in the state of Bihar. No detailed study, especially in the Ganga and some of its tributaries was conducted until more than 100 years later (Sinha 1996). However, even this study was far from complete, as it was mainly conducted in the mainstem of the Ganga. When interviewed, the locals in North Bihar reported that about 40-50 years ago during monsoon, the *susu* were frequently sighted in all the rivers, including very small rivers, and connected water bodies. But, unfortunately, no baseline data on the status are available.

Though a few papers on the Ganges river dolphin were published from Bihar earlier (Nath 1974, Gupta 1986, Ali 1992, Singh and Ahmed 1994, Kumar 1996) nothing specific is mentioned about its status and the reports carry only a general account of the species. Moreover, the papers record only casual observations on the animal in the River Ganga. Based on a systematic study, Sinha (1996, 1997 and 1999), Sinha *et al.* (2000) reported the current status and distribution of the *susu* in the Ganga and many of its tributaries. Though the overall estimate of *susu* abundance in the entire distribution range is not known, the largest sub-population occurs in the mainstem of the Ganga and its tributaries in Bihar. Most of the tributaries or parts thereof are yet to be surveyed thoroughly and these surveys were conducted in an effort to bridge this gap.

STUDY AREA
(Fig. 1)

River Son: The River Son originates from Amarkantak Hills at Sonabhadra, in Madhya Pradesh, at an elevation of 600 m. It flows northwards through Madhya Pradesh, Uttar Pradesh and Bihar before it discharges into the Ganga at Haldi-Chhapra village near Maner, about 35 km upstream of Patna. In Uttar Pradesh, it receives the Rihand tributary across which the Rihand dam was constructed in 1963. Though the Son is a perennial river, the main source of water is rain. Its total length is 784 km of which about 300 km are in Bihar. It enters the state of Bihar near the village Domarkhoha in Rohtas district. After flowing for about 35 km in Bihar, it receives the River North Koel from Chhota Nagpur Plateau of South Bihar (now Jharkhand State). About 65 km downstream of the confluence, the Son Barrage was constructed in 1965 at Indrapuri, about 15 km upstream of Dehri, to divert the river water through three irrigation canals — Patna Canal on the right side and Western Canal, which is divided into Buxar and Ara Canals on the left side. A weir

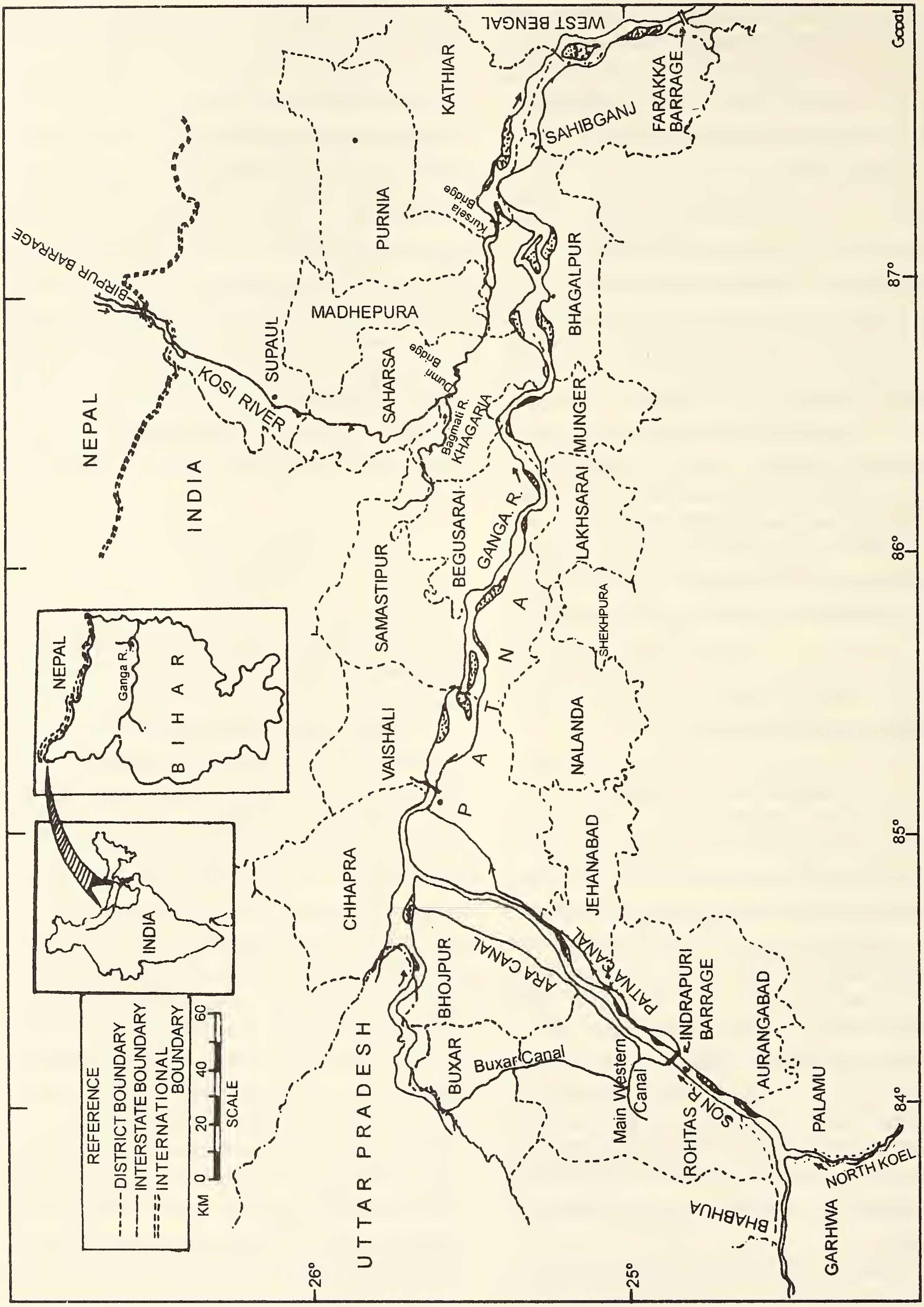
NEPAL
INDIA
BIRPUR BARRAGE
KOSI RIVER
SUPAUL
MADHEPURA
SAHARSA
Dumri Bridge
Bagmati R.
KHAGARIA
PURNIA
Kursela Bridge
KATHIAR
WEST BENGAL
SAHIBGANJ
FARAKKA BARRAGE
BHAGALPUR
MUNGER
LAKHSARAI
SHEKHPURA
GANGA R.
BEGUSARAI
SAMASTIPUR
VAISHALI
PATNA
NALANDA
JEHANABAD
CHHAPRA
BHOJPUR
ARA CANAL
PATNA CANAL
INDRAPURI BARRAGE
AURANGABAD
BUXAR
Buxar Canal
Main Western Canal
SON R.
ROHTAS
PALAMU
NORTH KOEL
GARHWA
BHABHUA
UTTAR PRADESH
NEPAL
Ganga R.
BIHAR
INDIA
REFERENCE
DISTRICT BOUNDARY
INTERSTATE BOUNDARY
INTERNATIONAL BOUNDARY
KM 0 20 40 60
SCALE
84°
85°
86°
87°
25°
26°

Fig. 1: Map showing course of the Rivers Kosi and Son in Bihar

constructed at Dehri in 1869-79 provided water for irrigation of 0.35 million ha of land. As the weir became old, the new barrage at Indrapuri was constructed which created a physical barrier for the migratory aquatic animals including dolphins of the river. The irrigation canals have converted the entire command area into a 'Grain Bowl' in Aurangabad, Jehanabad, Patna, Rohtas, Bhojpur, Kaimur and Buxar districts of Bihar. But this left almost no water downstream of the barrage to maintain its status as a river. The bed of the river consists mainly of coarse sand, which can retain little organic detritus. Extraction of sand as building material throughout this stretch of the river has added to the degradation and destruction of the river habitat.

River Kosi: The River Kosi (965 km) originates in Tibet at an altitude of 5,490 m and flows through Nepal; after running for *c.* 285 km in Bihar it joins the Ganga near Kursela in Katihar district. The Kosi is formed by the convergence of three rivers, the Sun Kosi, Arun Kosi and Tamur Kosi in Nepal. After the confluence, the river flows through a narrow gorge for 10 km and enters the plains at Chatra, traverses another 25 km and enters India near Hanuman Nagar. The total drainage area is 74,500 sq. km of which 11,000 sq. km lies within India.

The Kosi basin is the third largest in area in India. Its waters have the highest rate of siltation among the rivers of the state (average annual suspended load is 2,774 tonnes/sq. km) and it has a steep gradient. The Kosi is a torrential river of the mountains that has a catchment area too large for its relatively short course. Due to these topographical and meteorological features it is rated as one of the most problematic rivers of the world and is noted for its rapidity and unstable banks. Thus, in about 200 years, the river has moved 112 km laterally from Purnea to its present position.

Average discharge in normal years for the Kosi is estimated to be 1,75,000 cusecs. The average run off during monsoon (June-September) is about 83% and only 17% in the rest of the year. July-August is the period of peak flow, whereas January-February is the leanest period (Datta Munshi and Datta Munshi 2000). The Kosi Barrage at Hanuman Nagar was commissioned in 1965 from which two canals take off on either side to irrigate nearly one million hectares of land in Nepal and India. The barrage is intended to prevent the river from moving sideways. The important tributaries of the Kosi are rivers Bagmati and Kamala Balan.

SURVEY METHODOLOGY

Downstream survey was conducted using country boats along the entire stretch of the rivers Son and Kosi. Following the recommendation of international experts (Perrin *et al.* 1989), direct count method was used to record the number of dolphins. Although searches were conducted continuously along the total length of the river under study, areas of confluence, meandering, downstream of sandbars etc. received greater attention. Search effort in these areas was maintained for at least thirty minutes to avoid missing extremely quiescent or long-diving animals. During survey, best, high and low estimates of the number of animals in the groups were recorded. The high and low estimate was used to reflect confidence in the accuracy of the best estimate. The low estimate was considered to be an absolute minimum count and the high estimate as maximum count. Identical best, high and low estimates were used to indicate a high level of confidence in our best estimate. Occasionally the dolphin appears to follow the boat, which adds uncertainty to whether the subsequent sighting is of a new or the same animal. In this case, a low estimate of zero was used to reflect the possibility of making double counts. The dolphin's long dive time, unpredictable movements and quiescent behaviour also make single counts unreliable.

During quiescent behaviour, the dolphin surfaces without an audible blow exposing only the uppermost dorsal surface of the melon. If subsequent surfacing, or confirmation by a second member of the team did not substantiate such a sighting it was given a best and low estimate of zero and high estimate of one. Estimates were arrived by concensus among the team of observers that initially sighted the dolphin.

When a sighting was made the size, sex and colour among other features were ascertained. Diagnostic characters for individual animals (visible scarring and deformities, ratio of rostrum length to the height of melon, etc.) were noted and sketched. Photographs were taken by a 35 mm SLR camera, equipped with a 300 mm telephoto lens and motor drive.

Data on the frequency of dolphin sightings per visit to habitat locations was recorded throughout the study and later processed.

RESULTS AND DISCUSSION

River Son: A field survey was conducted in River Son between February 22 and 28, 2001. The survey started from a small tribal village Domarkhoha located at the Uttar Pradesh - Bihar border. Markings of large soft-shell turtles on the sand bar were seen, but no dolphin was sighted. Farther 5 km downstream at Belduria ghat / Newaria ghat, the locals informed that no aquatic wild animals except large soft-shell turtles were found in the area. However, a good number of dolphins and crocodiles had been reported in the river about 40-50 years ago. The Kaimur hill range is on the left bank (Rohtas district, Bihar) of the river between Domarkhoha and Newaria ghat. After this ghat, the river channel meanders towards the right bank (Garhwa district, Jharkhand) and a large island of about 100-150 sq. km has been formed which is used for farming. On the left bank, a 1-3 km wide plain is heavily cultivated for wheat, potato and vegetables. The river flows close to the left bank again at Teura ghat. No dolphin was sighted in this stretch. As reported by a fisherman, there used to be many deep pools of water in the river, but a high rate of siltation had filled up all these pools resulting in loss of habitats of dolphins and crocodiles. About 10 km downstream of Teura ghat is Uli ghat on the left bank. Opposite Uli, the River North Koel from Daltongunj and Garhwa districts discharges into the Son. However, the main channel of the Son flows close to the left bank. In spite of good habitats for dolphins near Uli ghat, no dolphin was sighted. It was learnt that about 10 years ago there used to be some dolphins in the area, but after the construction of the Rihand Dam in Uttar Pradesh the flow of the river had reduced which had affected the dolphin population. Another local fisherman informed about the killing of one dolphin about 15 years ago at village Jhitikia opposite Amjhore, about 30 km downstream of Uli. Earlier, the fishermen of village Deuri, located near Jhitikia, practised dolphin oil fishing. Frequent sightings of otters by the locals were reported near this ghat (river bank).

The river channel is highly braided and several small as well as large sand bars have been formed in the river downstream of Uli. The bed consists of coarse sand, mainly quartzite. The flow in the river increases after the North Koel joins the Son at village Tilothu, about 10 km upstream of Son barrage. It was reported that after construction of the barrage at Indrapuri in 1965, dolphin migration stopped and no more dolphins are sighted now. However, during the flood every year juvenile gharials occasionally drift into this area. Locals reported the killings of soft-shell turtles and presence of otters in the river in this area. About 200 fishermen fish in the river at Tilothu. The depth of river water was only about 50 cm to a metre at most places and many times it was difficult for a boat to float down in the highly braided river.

A large number of sandbars occupied by grasses and other thick vegetation have formed behind the barrage. They provide good habitat for otters and many species of migratory birds. The local fishermen informed us of sightings of dolphins below the barrage during the high floods every year. They migrate up to the barrage from the Ganga river about 200 km downstream.

About 18 km downstream of the barrage is the 3.06 km long Dehri Road Bridge, commissioned in February 1965. The river channel is highly braided and the depth of the river flow is insufficient to float even a country boat. Farther 30 km downstream of Dehri — a ferry ghat, is Mahadeva ghat on the left bank and Daud Nagar on the right bank. The river bed is more than 3 km wide and is widely used for vegetable farming, both at Dehri and Mahadeva ghats. Most of the fishermen were busy in farming activities. A few of them were found doing subsistence fishing using small drag nets. A local fisherman informed us of the sighting of dolphins occasionally during flood season only. Otters are also sighted during the rainy season. The soft-shell turtles are found and killed during summer season. About 40 km downstream of Mahadeva ghat is Malhi Patti ghat on the right bank near Baiderabad. No dolphin could be sighted in this stretch; however, locals informed that during monsoon 3-7 dolphins were sighted every year. Heavy siltation in the river has destroyed the habitat of the *susu*. Otters are reportedly sighted occasionally near the Malhi Patti ghat. Turtles are found mainly during the monsoon. Farther 5 km downstream near Arwal is Ahiyapur ghat where a very good habitat for dolphin with eddy counter-current exists, but no dolphin was sighted. However, locals informed that during monsoon 10-15 dolphins are sighted here. Reportedly otters and turtles are also found. It is an important fish spawn collection centre in the monsoon. Sighting of five adult dolphins during the last monsoon of 2000 at Mohammadpur ghat, 20 km downstream of Arwal was reported by a local fisherman. During the survey, water flow in the River Son at this ghat was not enough to sustain a dolphin population in this season. Similarly, at Udaipur ghat near Pali, otters were found in the boulder pitched river bank, but no dolphin was sighted. It was reported that dolphins could be seen only during monsoon. The killing of a dolphin, three years ago, was reported by the locals. At Koilwar, the biggest site of sand mining in the River Son, 15-20 *susu* were reported during the monsoon. Earlier the dolphins used to be killed here by harpooning. The local fishermen consume both the meat and oil of the dolphin. The drift gillnets with large mesh size are dangerous for dolphins during monsoon as they get entangled in these net.

River Kosi: A survey in the River Kosi was conducted between March 2 and 10, 2001. Sighting records of dolphins are given in Table 1. The survey was started from the Kosi Barrage at Birpur. Water depth in the reservoir of the barrage was only about 5 m. The river water was being diverted to irrigation canals and almost no water was allowed to flow into the river downstream of the barrage. Hence, the river water below the barrage was very shallow, and not enough to sustain dolphin population below the barrage. When the gates of the barrage were opened in April, the dolphins from farther downstream moved to the barrage site. In April 1994, dolphins were sighted here (Sinha *et al.* 2000). One or two dolphins are reportedly killed here every year. The locals reported that the dolphins cross the barrage gates both ways in the monsoon season. This needs to be confirmed, but if true it is good for the survival of the dolphins not only in India but also in Nepal. Further 42 km downstream of the barrage at Bhaptiahi, two dolphins were sighted. Here the water depth was about 5 m. As water in the river in this stretch was quite low no dolphin was sighted between the barrage and Bhaptiahi. Poison-fishing in the floodplain wetlands was reported by the local fishermen, as also killing of soft-shell turtles. The river channel was highly

Table 1: Status of the Ganges dolphin in the River Kosi during March, 2001

Place	GPS Reading	Distance from Kosi Barrage (in km)	No. of Dolphins H	B	L	No. of Groups of Dolphins
Kosi Barrage	26° 31.24' N 86° 56.03' E	0	-	-	-	-*
Bhaptiahi	26° 18.31' N 86° 44.06' E	42	-	-	-	-*
Sujanpur	26° 13.18' N 86° 37.48' E	60	8	7	6	3
Situhar Ghat	26° 05.39' N 86° 30.40' E	72	6	5	5	1
E 2 Ghat	26° 00.98' N 86° 28.10' E	78.3	9	8	8	2
Baluaha Ghat	25° 52.49' N 86° 27.05 'E	92	2	2	0	1
Dengrahi Ghat	25° 43.49' N 86° 30.07' E	102	9	8	8	2
Badla Ghat	25° 34.17' N 86° 35.34' E	135	10	9	9	2
Chautham Ghat	25° 33.01' N 86° 39.32' E	156	4	4	4	1
Dumri Bridge	25° 32.46' N 86° 42.89' E	167	3	3	3	1
Vijay Ghat	25° 25.17' N 87° 05.13' E	220	20	17	16	3
Kursela	25° 25.39' N 87° 13.57' E	270	16	14	14	3

H - Highest, B - Best, and L - Lowest; Total No. of the dolphins: H-87, B-78, L-73; * - Reported by locals

braided and shallow in this stretch. Farther downstream, four adults, two sub adults and one calf dolphin were sighted at Sujanpur, a village on the left bank near Thirbitia. The locals were expecting the number of dolphin to increase up to 20-25 after the gates of the barrage would be opened in April. At this site, two channels of the Kosi join resulting in increase in water flow. The water depth near the village was 6 to 8 m. Locals here do not kill dolphins, though turtles and avifauna were poached. Otters were reported in the area. About 9 km downstream, a very good dolphin habitat was found near the spur, but no dolphins were sighted. However, just 3 km further downstream at Situharghat three adults, two sub-adults and one calf dolphin were sighted (Highest 6 - Best 5 - Lowest 5) in one group. The locals reported killing of a dolphin at this site. Farther downstream, a highest of 9 and 8 each of best and lowest **count of dolphins**

(4 adults, 3 sub-adults and one calf) were sighted at E2 Ghat (93.2 km from the barrage). About 20-25 hard-shell turtles were also sighted. Erosion of the left embankment was noticed here. The locals reported degradation of dolphin habitat due to the erosion. Incidental killings of dolphin by gillnets were reported, however, no intentional killing was reported. Soft-shell turtles of 20-40 kg were reported at this site. Poison-fishing in floodplain wetlands was reported by the locals. The fishing activity was found to be very low. Fourteen kilometres further downstream is Baluaha ghat, another Ferry ghat. The river flows close to the left bank in this stretch. One dolphin was sighted here, however, the locals reported sighting of a good number of dolphins around the year. A large number of small turtles were also sighted. Ten kilometres further downstream is Dengrahi ghat where a highest of 9 and 8 each of best and lowest counts of dolphins were sighted in two groups including 6 adults and 3 sub adults. It was a very good habitat for the dolphins and the river was flowing mainly along the left bank. Gharials were reportedly sighted here. Soft-shell turtles up to 50 kg are killed regularly, however, dolphins are not killed here according to the locals. About 23 km further downstream is Koparia, 125 km downstream of the barrage. The east embankment of the Kosi terminates here. The river channel was highly braided and it was impossible for a boat to float downstream from Koparia.

The survey was resumed from Badla ghat in River Bagmati, an important tributary of Kosi. In this area, the highly braided channel of River Kosi flows parallel to Bagmati being separated only by 7 km. A channel of Kosi discharges into Bagmati upstream of Badla ghat. Near the Badla ghat railway bridge, a highest of 10 and 9 each of best and lowest counts of dolphins, including 6 adults, 3 sub-adults and one neonate were sighted in two groups. The river water was quite deep and meandering, and with erosion, eddy counter-currents were creating a good habitat for the dolphins. The water current in the river was very slow but the deeper zone sustained a good population of the dolphins. At Chautham ghat, 21 km farther downstream, 4 adult dolphins were sighted. Ten kilometres downstream of the Chautham ghat, the Bagmati joins the Kosi near Dumri Road Bridge. The Bagmati is deeper than Kosi near the confluence. Absence of dolphins, at the confluence of Bagmati and Kosi, was disappointing. The local fishermen reported non-availability of fish in the area as a reason for the absence of the dolphins.

Three adult dolphins were sighted about 2 km downstream the Dumri bridge. Dolphins are reportedly neither killed nor eaten by the locals in this area. The dolphin oil is used only as folk medicine. Otters are occasionally sighted farther 35 km downstream at Vijay ghat, Naugachhia where a highest of 20, best of 17 and lowest of 16 dolphins in three groups were sighted. The villagers here killed dolphins and reportedly over 30 containers of dolphin oil were available on that day in the village. Here the river channel was very wide (about 3-4 km) and water near the right bank was about 15 m deep. Downstream from Vijay ghat and about 1 km upstream of Kursela Bridge a dry channel of Kosi, Chhoti Kosi joins the main channel — the Bari Kosi. At the confluence of the two, a highest of 16 and 14 each of best and lowest counts of dolphins including 8 adults, 4 sub adults, one calf and neonate each were sighted. Four dolphins were sighted in the dead channel. Subsistence fishing with lift-net and cast-net was observed here. A local businessman accompanying our team up to this point informed us that a large (201.5 kg) dolphin was caught at Kursela in 1995 and he had transported it to Siliguri fish market himself. Otters were reported to be abundant here. The Kosi discharges into the Ganges 3 km downstream of Kursela Bridge.

Thus, in the Kosi a highest of 87 and best of 78 dolphins were sighted distributed almost along the entire stretch of the river. As the river channel is highly braided many more must have been missed.

Threats to the Survival of Dolphins

The main threats to dolphin survival are the construction of barrages, heavy siltation, farming in the river bed using chemical fertilisers and organochlorine pesticides, use of detrimental fishing gill nets, shortage of fish in the rivers, and incidental as well as intentional killings of the dolphin for oil and meat. The barrages have created a physical barrier for all the migratory species of the rivers, including dolphins. As there is no industry and urban settlement on the banks of the two rivers, the possibility of organic pollution is remote. However, non-point sources of pollution, namely chemical fertilisers, organochlorine pesticides and heavy metals cannot be ruled out.

CONSERVATION MEASURES

The heavy siltation in the rivers has degraded the dolphin habitat. There is a serious need for mass scale plantation in the catchment area of the rivers to reduce the silt load entering the river system. For this, international efforts are required as the Kosi flows through Nepal and the greater part of the silt load originates there. A minimal flow of water in the rivers must be allowed even during the lean season, so that the dolphin population can survive and migrate. Another serious need is fishery regulation in the rivers. No effective regulation exists. The detrimental gill-nets must be banned and only dolphin friendly nets should be allowed. The efficacy of legal measures to protect dolphins is non-existant. Hence, there is a need to motivate wildlife and other administrative officials to implement the Wildlife (Protection) Act efficiently. An alternative fish attractant, other than dolphin oil that is used throughout the state, should be identified.

Recently, fish scrap oil has been field-tested for three years and found to be a good alternative to dolphin oil as fish attractant (Sinha 2002). However, there is again a serious need of a long term extension programme for educating the fishermen to use the alternative fish attractant.

Education and awareness programmes to educate the target group, i.e. fishermen, officials, school and college children, and the common man will be helpful in conserving the dolphin.

Periodical monitoring of the dolphin population will help in evaluating the effects of Dolphin Conservation Programmes, if any.

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CROP DEPREDATION BY WILDLIFE ALONG THE EASTERN BOUNDARY OF THE KALAKAD-MUNDANTHURAI TIGER RESERVE, SOUTHERN INDIA[1]

(*With two text-figures*)

Punidan D. Jeyasingh[2,3] and Priya Davidar[2]

Key words: *Sus scrofa cristatus*, wild pigs, crop loss, crop raid, human-wildlife conflict, electric fence

Crop raiding patterns by wildlife at ten villages along the eastern boundary of the Kalakad-Mundanthurai Tiger Reserve (KMTR), southern India were studied. The Indian wild pig (*Sus scrofa cristatus*) was identified as the major crop pest in this area and the crop loss caused by it was quantified. The effectiveness of an electric fence to prevent crop raids by wild pig was also assessed, comparing (1) mean group size of pigs, (2) extent of damage in sq. m, (3) actual and potential loss, and (4) frequency of wild pig raids. The actual loss was estimated at 257.19 kg ha^{-1} accounting for approximately 7% of the actual produce. The electric fence was not effective in preventing crop raiding by the wild pig. The number of wild pigs was not correlated with the extent of damage. Extent of damage might be a factor of time spent in the paddy field, suggesting that wild pigs might raid paddy fields for habitat requirements rather than for nutritional requirements. It is vital to understand crop-raiding patterns prior to the implementation of control strategies.

INTRODUCTION

Strategies for reconciling human needs and conservation interests in areas abutting nature preserves are critical to the success of conservation plans (Gradwohl and Greenberg 1988, Western and Pearl 1989). Crop depredation by wildlife can occur more frequently than the highly publicized and prioritized, but sporadic livestock raids. Over the years, farmers have developed a variety of measures such as fencing, culling, dogs, firecrackers, fire and drums to chase away pest species and reduce crop loss to wild animals. Today, when many crop raiding species are protected by law and are focal points for conservation, the need for effective and long-term control methods is felt. Some of the control measures include physical barriers, selective culling and environmental control methods, such as providing better habitat in the forest interiors, away from human habitation (Sukumar 1992). Recently, electric fencing has become one of the methods widely used by both private farmers and the government to prevent crop raids by wild animals.

In a predominantly agricultural and densely populated country like India, conflicts between humans and wild animals are frequent, and preventing conflict should be a conservation priority (Sukumar 1992). Damage by the Asian elephant (*Elephas maximus*) has been estimated at *c.* $0.5 million/per year in southern India (Sukumar 1989). Although considerable work has been done on the crop damage patterns and management strategies for larger wildlife, such as the elephant and tiger (landmark studies include Sanyal 1987, Sukumar 1991), work on wild pigs is sparse, except for Tisdell (1982), and Ahmed (1991).

Crop damage patterns along the eastern boundary of the Kalakad-Mundanthurai Tiger Reserve by different wildlife species and wild pigs in particular were analyzed and crop loss due to wild pigs, the major pest in the area, were

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estimated. The study also attempted to understand the possible cues for crop raiding by the wild pig in the area, and to suggest effective control measures. An electric fence, erected with the aid of the World Bank, was assessed for its effectiveness against the wild pig.

STUDY AREA

The study was carried out from December 1998 through March 1999 in ten villages located in the eastern boundary of the Kalakad-Mundanthurai Tiger Reserve (KMTR), southern India. KMTR is situated at 08° 25' - 08° 35' N and 77° 25' - 77° 35' E and covers 795 sq. km of the southernmost protected area in the Western Ghats complex. Along the northeastern boundary of the Reserve, an 8.7 km long electric fence was erected in 1996 with partial funding from the World Bank to control crop damage by wildlife (Fig. 1). The fence is about 160 cm high and consists of 7 wires running parallel to the ground attached to granite posts at intervals of 2.5-3 m. Wires 2 and 5 are ground wires. The rest of the wires have an output of 36V generated from a 12V solar battery. The lowest wire is *c.* 10 cm from the ground and the second wire (earth wire) is *c.* 30 cm from the ground.

Ten villages located along the 26 km eastern boundary of the KMTR were selected for the study. Four villages were located in the Mundanthurai area and were separated from KMTR by the electric fence. The fifth village abutting the Mundanthurai section (Pudukudierrupu) was not protected by an electric fence. The other five villages bordered the Kalakad section of KMTR (Fig. 1). All the study villages had lowland teak dominated deciduous forests, thickets, and scrub jungles, representative of the vegetation of the buffer zone of KMTR. All the crops grown along the boundary, such as paddy, banana, sugarcane, and groundnut, were also cultivated in the 10 study villages (Table 1).

Table 1: Details of the Study Villages

S.No	Village	Vegetation type adjoining the village	Electric Fence
1.	Pothigaiadi	Secondary Thicket	*
2.	Anavankudierrupu	Secondary Thicket	*
3.	Kilanai	Secondary Thicket	*
4.	Arunachalapuram	Secondary Thicket	*
5.	Pudukudierrupu	Rocky/ Grassland	x
6.	Sivapuram	TDDD	x
7.	Mungiladi	Secondary Thicket	x
8.	Manjuvelai	TDDD	x
9.	Kalliyar	TDDD	x
10.	Chidamparapuram	Secondary Thicket	x

TDDD = Teak Dominated Dry Deciduous, Present - *, Absent - x

METHODS

Farmers' Perceptions

A questionnaire was circulated among farmers in the 10 study villages to estimate wildlife raids, crop loss, and other relevant information. Results from the questionnaire indicated the actual or realized yield and crop loss due to wild pigs. Potential yield and crop loss estimates were based on quadrat data. Both the questionnaire as well as quadrat data were used to estimate crop loss because farmers tended to underestimate production and overestimate crop loss due to wildlife.

Crop Raids

Information regarding the wildlife species involved in the raid, group size, and the time of raid were obtained from the farmer who had witnessed the raid or through direct observation. The species responsible for the highest proportion of raids and damage in the area was identified as the major crop pest species.

Crop Damage

Crop damage was assessed within 24 hrs of the damage. The site was visited, and the mean plant density (MPD) was estimated to assess crop loss. MPD measurements were determined in the

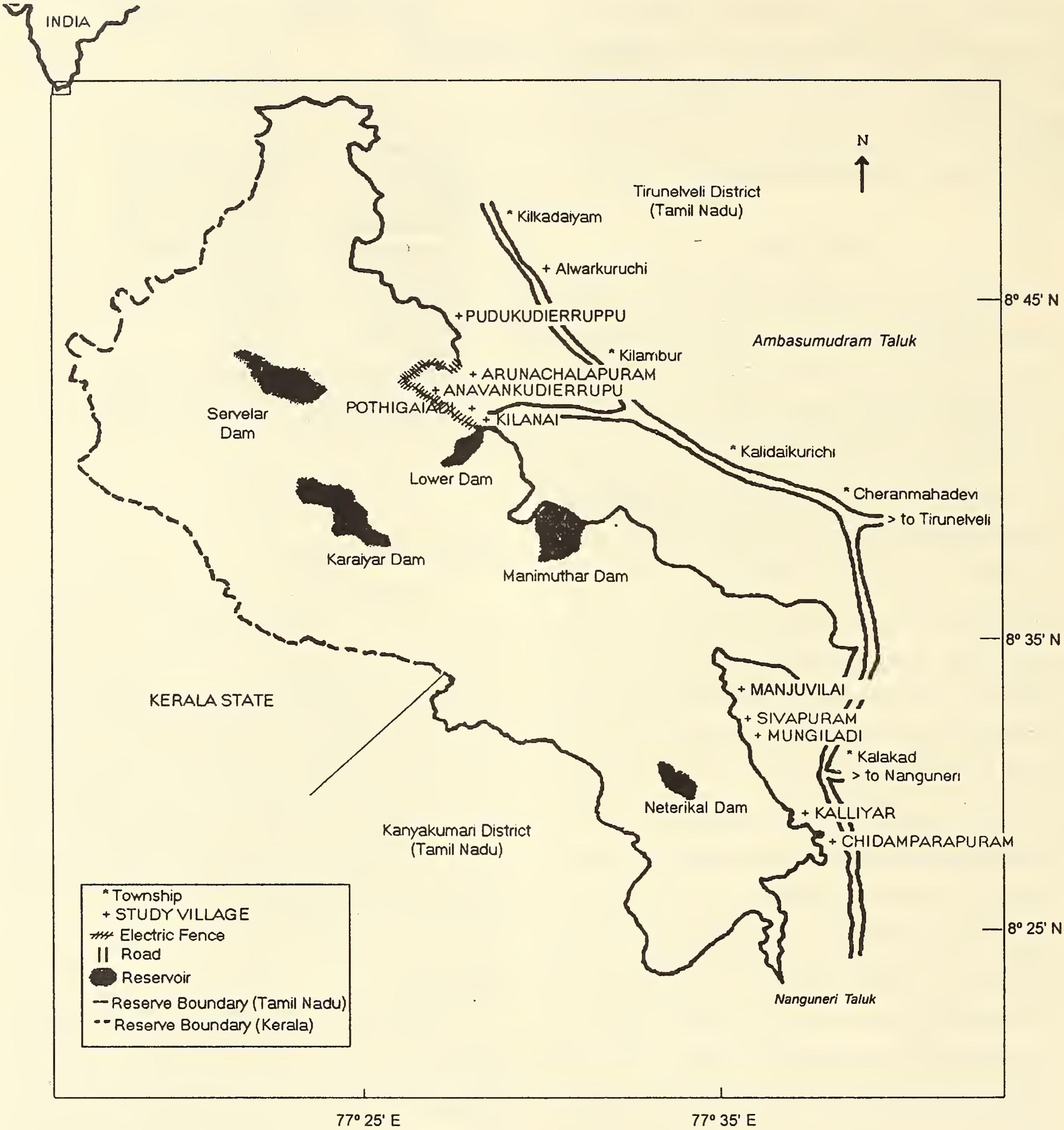
INDIA
N
Tirunelveli District
(Tamil Nadu)
* Kilkadaiyam
+ Alwarkuruchi
+ PUDUKUDIERRUPPU
* Kilambur
Ambasumudram Taluk
+ ARUNACHALAPURAM
+ ANAVANKUDIERRUPU
POTHIGAI
+ KILANAI
Servelar Dam
Lower Dam
* Kalidaikurichi
* Cheranmahadevi
> to Tirunelveli
Karaiyar Dam
Manimuthar Dam
8° 45' N
8° 35' N
8° 25' N
KERALA STATE
+ MANJUVILAI
+ SIVAPURAM
+ MUNGILADI
* Kalakad
> to Nanguneri
Neterikal Dam
+ KALLIYAR
+ CHIDAMPARAPURAM
Kanyakumari District
(Tamil Nadu)
Nanguneri Taluk
* Township
+ STUDY VILLAGE
Electric Fence
Road
Reservoir
Reserve Boundary (Tamil Nadu)
Reserve Boundary (Kerala)
77° 25' E
77° 35' E

Fig. 1: Kalakad-Mundanthurai Tiger Reserve

damaged and undamaged sites in the field. MPD was estimated by laying 12-30 quadrats (30 cm x 60 cm) at random in the undamaged part of the field. The field area was noted. The total number of plants in the field (P_u) was estimated by

P_u = MPD x Area of the field in sq. m (Eq 1)

A sample of five plants was taken from each quadrat for which the number of grains and mean weight per grain were calculated.

The damaged area was identified as the portion of the field where all the stalks had been flattened to the ground and could not be harvested. The average length and width or radius within the damaged areas were measured and the area of the closest resembling regular shape, i.e., square, rectangle, or circle was calculated in sq. m. The total number of damaged plants (P_d) was calculated using the formula

P_d = MPD x damaged area in sq. m(Eq 2)

The number of grains per damaged plant was counted and weighed. The potential produce (standing crop) was estimated by

$P_p = P_u N_g W_g / 1000$(Eq 3)

where, P_p = Potential produce in kilograms,
P_u = total number of plants in the field,
N_g = mean number of grains per plant, and
W_g = mean weight of one grain in grams.

The potential loss (P_l) in kilograms due to crop damage can be estimated by

$P_l = P_d N_g W_g / 1000$

where P_d = total number of damaged plants

The average actual produce (kilograms of paddy sold by the farmer in the market) was estimated using the farmer's claim and a brief survey of the buyers. The market value of the crop was obtained from the farmers and wholesalers to arrive at the actual loss in kilograms and rupees. The potential loss was the loss measured during this study based on the yield measured by the quadrat study. Loss per raid thus calculated was used to extrapolate the loss for a month using the mean number of wild pig raids in each of the ten study villages.

Effect of the electric fence

The villages were divided into villages protected by an electric fence and unfenced villages. A t test or its non-parametric equivalent, the z test, was used to test for significant differences between the two in the following parameters:

1. Mean group size of pigs.
2. Extent of damage in sq. m.
3. Actual and potential loss.
4. Frequency of wild pig raids.
5. Frequency of larger wildlife sightings on cropland.

RESULTS

Crop raiding patterns

A total of 121 farmers were interviewed, and 39 instances of fresh crop raids were observed. Of these, 35 were on paddy fields, 3 on banana plantations and 1 on sugarcane. The results show that of the 11 species of crop pests reported, wild pigs were the most and accounted for 99% of the crops damaged during the study (Table 2). Crop raiding patterns of wild pigs on paddy were dependent on the age of the crop (Ahmed 1991, Jeyasingh 1999). The ears of paddy were nipped off, chewed well, the juice ingested and the fibre spat out. In banana plantations, wild pigs fed on the stem, flower, and fruit by reaching up on their hind legs and biting the stem to bring down the canopy. On younger plants, they nosed around the plant to expose and feed on the tender shoot. Sugarcane stems were consumed voraciously from the bottom for the juice and fibre.

Other wildlife reported to stray outside the Reserve boundary included larger herbivores like the sambar (*Cervus unicolor*), chital (*Axis axis*), Asian elephant (*Elephas maximus*) and carnivores such as leopard (*Panthera pardus*), wild dog (*Cuon alpinus*) and sloth bear (*Melursus ursinus*). Apart from these, smaller mammals such as black-naped hare (*Lepus nigricollis*), common palm civet (*Paradoxurus hermaphroditus*) and the jungle cat (*Felis chaus*) were also sighted (Table 2).

Data on wild pigs only, the major pest on paddy crop, was considered for analysis. The frequency of wild pig raids in the ten study villages was proportional to the area of land under cultivation (Table 3). The mean number of crop raids per month by wild pigs in the fenced

Table 2: Wildlife raids on croplands in 1998-99 in the ten study villages

Common name	Local name	Latin name	IUCN Status	Number of sightings	Villages	
					F	UF
Leopard	Puli	*Panthera pardus*	EN	4	1	3
Wild dog (Dhole)	Chen Nai	*Cuon alpinus*	EN	2	1	1
Sloth bear	Karadi	*Melursus ursinus*	EN	6	1	5
Sambar	Mila Maan	*Cervus unicolor*	LR/CD	14	4	10
Chital	Pulli Maan	*Axis axis*	LR/CD	4	1	3
Black-naped hare	Muyal	*Lepus nigricollis*	DD	12	5	7
Jungle cat	Kattu Punai	*Felis chaus*	VU	86	54	32
Common palm civet	Mara Nai	*Paradoxurus hermaphroditus*	VU	3	3	0
Bonnet macaque	Korangu	*Macaca radiata*	VU	7	6	1
Indian wild pig	Kattu Panni	*Sus scrofa*	LR/CD	121	68	53

IUCN = International Union for Conservation of Nature and Natural Resources, F = Fenced villages, UF = Unfenced villages, EN = Endangered, LR/CD = Low risk/ conservation dependent, VU = Vulnerable, DD = Data deficient

villages was 21.80 and 22.54 in unfenced villages (Table 4). The mean group size was about 11 animals in each category (Table 4). The crop loss between the fenced and unfenced villages was not significantly different (Table 4).

The regression between the number of wild pigs and damaged area was not significant ($r^2 = 0.09$), suggesting that the extent of damage was not dependent on the number of pigs involved in the raid.

Economic value of crop loss

The overall crop damage in all the villages studied was estimated to be Rs. 16,270.65, at Rs. 4.40 per kg of paddy (Ministry of Agriculture, Govt. of India) in all the ten villages during the study. The approximate loss of paddy to wild pigs was 7% of the actual produce in all the villages (Fig. 2). Potential and actual yield were estimated at 5270.29 kg ha^{-1} and 3697.93 kg ha^{-1} respectively. The potential loss was estimated at 366.56 kg ha^{-1} and the actual loss was 257.19 kg ha^{-1} (Fig. 2).

Effects of the electric fence on crop loss

There were frequent large mammal sightings in the unfenced villages compared to the fenced villages (Table 2). The mean quantity

Table 3: Sampled area and estimated crop loss per village

Village	No. of raids studied	Area of the Field (m²)	Damaged Area (m²)	Estimated Potential Produce (kg)	Loss in kg	Loss per raid in kg
Sivapuram	4	928.2	69.405	632.77	44.85	11.21
Chidamparapuram	4	617.5	43.65	530.75	33.95	8.48
Mungiladi	3	183.93	30.54	132.71	22.04	7.34
Kalliyar	2	125.6	28.05	106.10	13.51	6.75
Manjuvelai	4	713	63.42	626.94	57.91	14.47
Pudukudierrupu	3	1450.8	68.52	714.03	31.50	10.5
Anavankudierrupu	5	655.05	50.84	583.45	50.12	10.02
Pothigaiadi	5	123.2	67.26	1387.3	71.88	14.37
Kilanai	3	172.5	26.08	143.7	21.49	7.16
Arunachalapuram	2	424.14	15.32	355.42	12.81	6.4

of paddy lost per pig raid in fenced villages was 9.48 kg, with Pothigaiadi recording a maximum of 14.376 kg/raid. In the unfenced villages, the mean loss was estimated at 9.65 kg/raid, with Manjuvelai recording the highest at 14.47 kg/raid (Table 3).

There was no significant difference (P = 0.05) in the loss estimates, raiding frequency, and wild pig group size between the fenced and unfenced villages during the study period (Table 4).

DISCUSSION

The study indicated that the wild pig was the major crop pest along the eastern boundary of the Kalakad-Mundanthurai Tiger Reserve. The wild pig causes significant damage to paddy, the major crop in the study area, accounting for about 7% of the actual yield. The extent of loss might vary, depending on the season and the year. The crop is damaged as the wild pigs wallow in the abundant mud and water in paddy fields. They consume the grain at only one stage, the 'milk maturity stage'; otherwise they do not eat any part of the paddy plant (Ahmed 1991, Jeyasingh 1999).

The Indian wild pig is a forest loving omnivorous mammal. Its diet includes roots, tubers, bulbs, fruit, insects, molluscs and remains of tiger and wild dog kills (Prater 1980, Tisdell 1982, Seshadri 1986). As it does not have sweat glands, the wild pig must drink regularly and wallow to regulate body temperature (Ahmed 1991). Therefore, it requires water sources, especially during the hot season. It prefers to remain in the shade of reeds and shrubs, which help in thermal regulation, and prefers open canopy and dense undergrowth at night (Tisdell 1982). It is crepuscular, although in areas where human interference is high, it is known to become nocturnal (Prater 1980). The home range of a sow tends to be 5-30 sq. km and that of a boar about 50 sq. km. The boar is mobile and is known to move long distances for food and mating opportunities (Prater 1980, Tisdell and Fadeer 1981). Group sizes vary with climatic conditions and a sounder of 10-15 individuals is common (Brander 1923, Prater 1980).

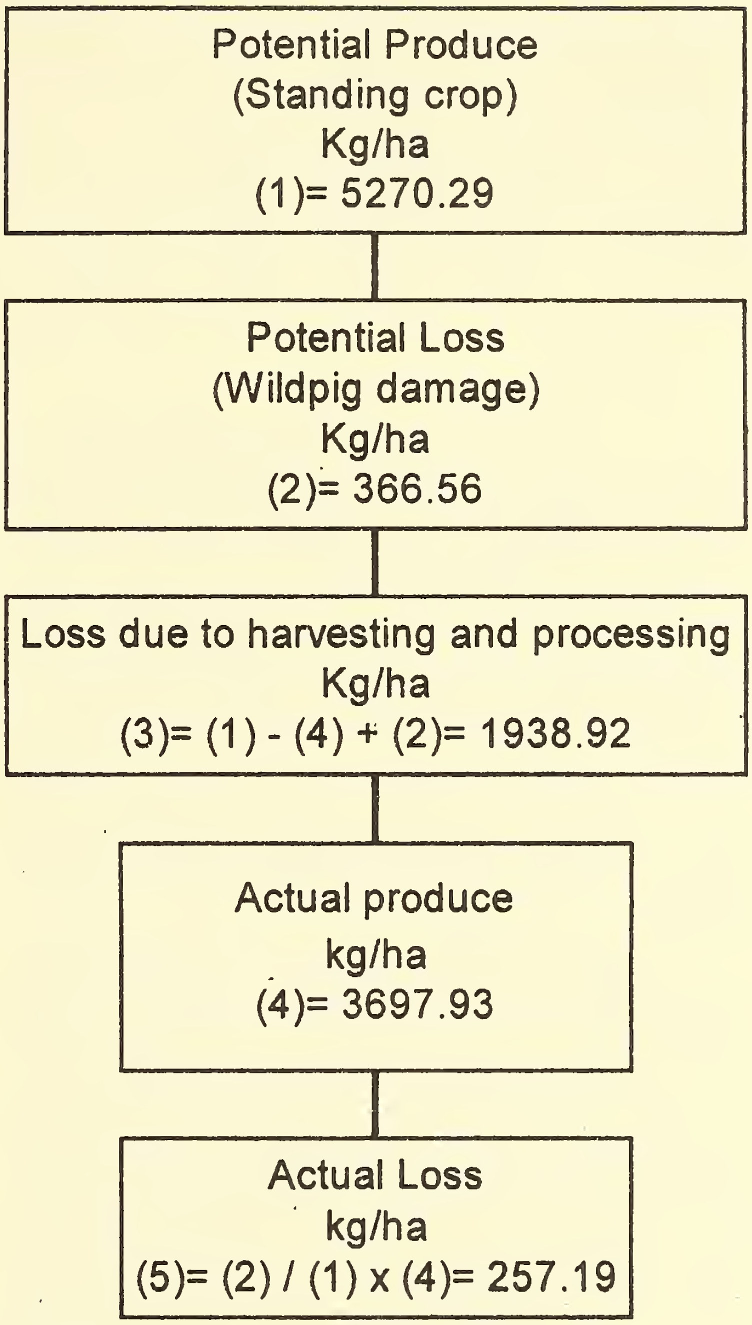

Fig. 2: Schematic representation of loss calculations

Until the 1960s, forests adjoining the study villages were disturbed periodically: clear cutting deciduous forests and planting commercially important species, construction of dams, intense cattle grazing and frequent fires (Joshua and Johnsingh 1989). As a result, plant species composition is dominated by fire resistant and

Table 4: Difference between raid frequency, group size of wild pigs and crop loss in fenced and unfenced villages

Parameter	Fenced			Unfenced			95% C I	Z	P= 0.05
	N	Mean	SD	n	Mean	SD			
Frequency	49	21.80	3.60	59	22.54	4.53	0.74 ±1.53	0.9526	*
Group size	45	11.27	7.05	56	11.26	7.53	0.01 ±2.85	0.2158	*
Crop loss	16	9.48	5.86	19	9.65	6.87	0.33 ±3.13	0.1078	*

* - not significant

highly silicified species (Johnsingh 1986). Moreover, the two major reservoirs within the Reserve, Karaiyar and Servalar may desiccate all potential wild pig wallows along the rivers inside the Reserve. The non-significant regression between number of pigs and extent of damage suggests that the extent of damage might be a factor of time spent in the cropland, suggesting that wild pigs might prefer the paddy fields mainly for the ambience rather than for forage.

The 8.6 km long electric fence erected with World Bank aid in 1996 does not appear to be effective against the major crop pest. There was no significant difference in raiding patterns of wild pigs and crop loss between the fenced and unfenced portions of the Kalakad-Mundanthurai Tiger Reserve's boundary. It is apparent that the fence was designed to deter larger mammals such as the elephants, sambar and chital. This might be because the fence is designed in such a manner that there is a gap of 40 cm (approximate to 10 different places in the fence) between the lowest live wire (first wire) and the next live wire (third wire), making it possible for smaller animals to slip through. Moreover, the second wire at about 30 cm from the ground is an earth wire, which might enable the larger pigs to penetrate the fence without getting an electric shock. We suggest that the gap between the three lower wires be reduced to eliminate penetration by wild pigs. The scrub dominated hills and private irrigation canals along the border are refuges for the sounders of wild pig once they are outside the fence.

It is evident that the fence has not been designed to control the wild pig. Preliminary studies must be carried out before a control or management project is conducted. The success of such a venture depends on its effectiveness in reducing crop damage by wildlife. The project should be monitored to assess its effectiveness. If crop damage continues despite such a project, it may create distrust among villagers towards the Forest Department, reducing their goodwill towards conservation efforts in the area. Human use of the landscape is a reality and must be dealt with in reserve design (Kramer *et al.* 1997), the importance of people in the success of conservation schemes has been stressed in both developed and undeveloped countries (McNeeley and Norgaard 1992, Kothari *et al.* 1996). It is suggested that the wild pig raids reported in this study be controlled as soon as possible, before local villagers completely lose faith in the forest department. It is further recommended that suitable habitats such as wallows be created within the Reserve for wild pigs, and wild pig incidence in cropland be tested after such environmental control measures.

Crop loss to wildlife in a country like India is a bane for conservation efforts, where farmers compete with wildlife for space and resources. Quantifying crop loss and identifying the cues for wildlife to raid crops are vital in developing efficient conservation strategies. Correct management and control measures are needed to ameliorate the economic loss incurred due to wildlife, and to cultivate conservation awareness among local communities.

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SMALL MAMMALS IN MONTANE ECOSYSTEMS OF THE NILGIRIS, SOUTHERN INDIA: THEIR ECOLOGY AND NATURAL HISTORY[1]

KARTIK SHANKER[2]

Key words: rodents, *Rattus rattus*, *Millardia meltada*, montane forest, grassland, plantation

Small mammals were studied in the montane ecosystems of the Nilgiris in the Western Ghats, southern India, from February 1994 to September 1996. A total of 35,000 trap-nights were sampled in various habitats including montane forests, grasslands, and man-made habitats such as *Eucalyptus*, *Pinus* and *Acacia* plantations. A total of nine species were trapped in the montane forest patches and three to four species in each of the other habitats. *Rattus rattus* was dominant in the montane forests, while *Millardia meltada* was dominant in the grasslands. Both species were found in plantations. The occurrence of *M. meltada* in the high altitude grassland is remarkable, as it is not found in such habitats elsewhere, nor is it found in intermediate habitats in the Nilgiris. Species richness and abundance of small mammals was high compared to other natural habitats in southern India. While various aspects of the demography, habitat utilisation and community structure were studied, many others, regarding small mammal population dynamics, which are pertinent to their conservation and that of their predators, still need to be addressed with extensive field studies. Though this particular field is in its infancy in India, it is hoped that this and other such studies will pave the way for more such work in the future.

INTRODUCTION

Small mammals have been studied extensively, including aspects of life history (see Fleming, 1979 for review) demography (Fleming 1975), insularity (Gliwicz 1980; Adler and Levins 1994), desert communities (Kotler and Brown 1988; Brown 1989), competition (Grant 1972) and habitat utilisation (August 1983). However, they have been largely ignored in India except in taxonomic accounts (Agrawal and Ghose 1969; Biswas and Tiwari 1966; Chaturvedi 1966; Ellerman 1961; Ellerman and Morris-Scott 1951; Ghose 1964), surveys and pest management studies in agricultural areas (Barnett and Prakash 1975; Sood and Guraya 1976; Prakash 1976, 1988; Prakash and Ghosh 1992; Karim 1994). The lack of concern for murid rodents in particular is perhaps reflected in the Indian Wildlife (Protection) Act (1972) where this family (which includes most rodents apart from the giant squirrels, flying squirrels and a few others) is relegated to Schedule V (vermin) and reduced to two entries, namely 'rats' and 'mice'. There is, however, a fairly large body of work on the distribution of rodents in the country, largely due to numerous surveys by the Zoological Survey of India. Notable amongst these is the pioneering work of Dr. Ishwar Prakash (Central Arid Zone Research Institute, Jodhpur) which includes extensive studies on the Indian desert gerbille *Meriones hurrianae* (Prakash 1964, 1969, 1981; Prakash *et al.* 1965; Prakash *et al.*, 1969; Prakash and Jain 1970; Prakash and Idris 1992), ecology of rodent communities in various ecosystems in northwestern India (Agrawal and Prakash 1992; Prakash 1975, 1994; Prakash and Gupta 1976; Prakash and Rana 1973; Prakash *et al.* 1971; Prakash *et al.* 1996, 1995) and rodents as pests in agriculture (Barnett and Prakash 1975;

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Prakash 1976, 1988; Prakash and Ghosh 1992). The Rodent Newsletter of the All India Coordinated Research Project on Rodent Control (Central Arid Zone Research Institute, Jodhpur) has, since the mid 1970s, provided a forum for issues on rodents as pests.

Apart from these efforts, however, the available information about rodents in natural habitats is minimal throughout most of India. Interest in small mammal studies amongst wildlife biologists and animal ecologists in India gradually increased in the early 1990s. While the latter are interested in theoretical aspects of community ecology and population biology, the former are more concerned about the role played by small mammals in ecosystems, especially as prey of small carnivores, some of which are endangered. Chandrasekhar (1989) and Chandrasekhar-Rao and Sunquist (1996) studied small mammal communities in various habitat types in the Anamalais. Small mammal communities were also examined in the context of fragmentation of rainforests in the Western Ghats (Mudappa, pers. comm.; Prabhakar 1998) and in plantations in Kerala (Bhat and Sujatha 1986). Other recent ecological work includes studies on habitat utilisation in three rodents in sandy habitat in the Thar (Mukherjee 1999), and rodents as a prey base for small carnivores in Sariska Tiger Reserve (Mukherjee 1998).

I studied small mammal (rodent and insectivore) communities in montane (shola-grassland) ecosystems in the Nilgiris in southern India. The population dynamics and community ecology of small mammals have been dealt with extensively; I review these results briefly. Firstly, it is clear that density estimation methods have to be developed or modified with tropical forests and tropical small mammal populations in mind, especially when densities are low (Shanker 2000a). Alternately, one must focus on questions that do not deal directly with densities, but with other parameters that can be measured with precision in tropical systems. In examining the demography of small mammal populations in shola patches, a comparison between populations in small and large fragments showed that while population fluctuations between fragments were asynchronous, fluctuations within large patches were synchronous (Shanker and Sukumar 1999). This requires closer examination in the context of fragmentation in the Nilgiris and other parts of the Western Ghats. The demography and community structure of these small mammal populations was related to fragment size and habitat characteristics of the montane patches (Shanker and Sukumar 1998). Interspecific competition appeared to be less important than other factors such as intraspecific competition and predation (Shanker 2000b). Differences in small communities in different habitats and the significance of plantations in the landscape were examined and metapopulation processes and landscape effects on these populations in the montane ecosystem were explored (Shanker, in press).

Since small mammal community ecology is a relatively new field of study in the tropics, and India in particular, a great many questions remain unanswered. In many ways, this study threw up more questions than it answered. I attempted to address some of these questions with field and laboratory studies. In this paper, I give a brief overview of the small mammal study in the Nilgiris, with an emphasis on the natural history and ecology of the various species. I also present some hypotheses, and questions that remain unanswered during the study.

STUDY AREA

The Nilgiris are located between 11° 10' - 11° 30' N and 76° 25' - 77° 00' E at the junction of the Eastern Ghats and the Western Ghats, in southern India. The study was conducted at higher altitudes (1,800-2,500 m above msl) of the Nilgiris which have a montane ecosystem, comprising of patches of stunted evergreen forest (locally called 'sholas') surrounded by grasslands. Though most grasslands have been replaced by exotic species such as wattle (*Acacia* spp.), pine (*Pinus roxburghii*), tea (*Camellia sinensis*) and blue gum (*Eucalyptus globulus*), the natural ecosystem remains intact in the southwest region of the Nilgiris plateau. The stunted montane evergreen forest patches, usually 1-10 ha in size with few exceeding 100 ha, are confined to depressions and folds in the mountain. They are extremely dense, with 5000+ woody plants (>1 cm d.b.h.) per hectare, and are dominated by the families Lauraceae, Rubiaceae and Symplocaceae (H.S. Suresh and R. Sukumar, unpubl. data). There is a sharply defined ecotone between the montane forest patches and the grasslands that are maintained by frost and fire (Meher-Homji 1984). The climate is highly seasonal, with a dry season extending from December to February, a pre-monsoon season from March to May, the southwest monsoon from June to August and a second wet season from September to November. Most of the areas sampled receive annual rainfall of 1,500-2,000 mm.

METHODS

Sampling Procedures

Live trapping of small mammals was carried out between February 1994 and September 1996. Montane forest patches and grasslands were sampled using 0.49 ha and 1 ha plots. Traps were placed at intervals of 10 m so that each 0.49 ha plot consisted of 49 permanently marked trap stations, in a square grid of 7 x 7 traps (the 1 ha plots had 100 trap stations, in a 10 x 10 configuration). Due to their size and shape, plantations were sampled using 0.45 ha plots (15 x 3 trap stations). A standard Sherman live trap (22.9 cm x 7.6 cm x 8.9 cm) was placed on the ground at each station, close to a tree, log, or any other appropriate runway. The traps were baited with grated coconut and rice. All trapped animals were identified, uniquely marked (Ear-punch, National Band and Tag. Co., Kentucky # 1538), sexed, weighed, measured and released. The traps were checked once daily between 0800 hrs and 1200 hrs. The plots were run for five consecutive nights during February-October 1994. Trap mortality was found to be particularly high towards the end of the trapping period in some seasons, and the trapping duration was thus reduced to three nights for the rest of the study (Shanker 1998).

Six montane evergreen forest patches, ranging from 2 to 600 ha, were extensively sampled using nine 0.49 ha plots and two 1 ha plots (see Shanker 1998; Shanker and Sukumar 1998). The sampling was primarily carried out in the Upper Bhavani region of the Mukurthi National Park and at Thaishola, about 20 km east of Upper Bhavani (which is about 65 km southwest of Udhagamandalam). Thaishola is the largest shola in the Nilgiris, (*c.* 600 ha) and the other sholas sampled ranged from 2 to 60 ha. Grasslands were also sampled using 0.49 ha plots. Both forest patches and grasslands were also sampled with 0.45 ha plots, which enabled comparisons with plots in anthropogenic habitats which had a similar design. Anthropogenic habitats - tea, gum, wattle and pine - were sampled using 0.45 ha plots, including wattle plantations of three different ages (Table 1). Additionally, a 0.90 ha plot was established in an old wattle plantation to study the interaction between *Rattus rattus* and *Millardia meltada*. Each plot was sampled several times, typically once during each season (= 'session').

Data Analysis

Various estimators were attempted using capture-mark-recapture models, but these could not be applied consistently to all species across all seasons (Shanker 2000a). Hence, we used the minimum number alive (Krebs 1966), which is the total number of animals of a particular species trapped during a trapping session.

Table 1: Trapping effort and habitat characteristics of the habitat types sampled in the Upper Nilgiris and Mudumalai Wildlife Sanctuary

Habitat	Plots	Sessions	Trap-nights	Canopy cover	Grass	Woody stems	Tree density	Height (m)
Grassland (0.45-ha)	9	19	3,486	Open	High	None	None	
Wattle - young	3	6	810	Open	Medium	High	None	3.2
Wattle - mid	1	4	540	Medium	High	High	Medium	4.1
Wattle - old	3	9	1,800	Closed	Low	Medium	High	9.9
Shola forest	15	89	*c.* 20,000	Closed	Low	High	Medium	11.5
Bluegum	2	6	810	Open	Low	Low	Medium	5.3
Tea	2	3	335	Open	Low	Medium	None	
Pine	3	10	1,350	Closed	None	None	Low	10.9

RESULTS

In all, 1,310 individuals were trapped in the sholas, grasslands and plantations with an overall trapping success of 10.6%. A total of 9 species were trapped, there were 8 species in montane evergreen forests, 3 species in the grassland, 3 species in wattle, eucalyptus and pine plantations, and 4 species in tea plantations (Table 2). *Rattus rattus* was the dominant species in the montane forest and comprised 60.9% of the total density, while *Millardia meltada* was the dominant species in the grassland. In the natural habitat (forest and grassland), the two species are mutually exclusive. While the former was trapped in the forest patches, the latter was the only rodent trapped in the grassland. An analysis of wattle stands of different ages shows that *Millardia* dominates young stands (grass-like habitat), while *Rattus* dominates the older

Table 2: Average density (MNA/ha) of rodents and shrews in the various habitats in Upper Nilgiris

Species / Habitat	Thai-shola	Other Sholas	Grass-land	Wattle young	Wattle mid	Wattle old	Blue Gum	Tea	Pine
Rodents									
Rattus rattus	14.7	12.4	0	0	5.0	16.6	4.0	8.4	4.0
R.r. rufescens	-	-	-	-	-	R	-	-	-
Cremnomys blanfordi	S	-	-	-	-	-	-	-	-
Mus famulus	L	L	-	-	-	-	-	R	-
Mus platythrix	R	R	-	-	-	-	-	-	-
Platacanthomys lasiurus	L	R	-	-	-	-	-	-	-
Millardia meltada	-	-	9.6	6.6	25.5	8.3	7.7	2.0	2.6
Vandeleuria oleracea	S	-	-	-	-	-	-	-	-
Funambulus sublineatus	V	V	-	-	-	-	-	-	-
Ratufa indica	V	-	-	-	-	-	-	-	-
Shrews									
Suncus montanus	4.3	4.3	1.2	2.2	4.4	4.3	2.5	0.7	2.0
Suncus dayi	L	L	R	-	-	-	-	-	-
Feroculus feroculus	-	*	-	-	-	-	-	-	-

Thaishola is the largest shola in the Nilgiris at 600 ha. S – Single capture, R – rare species i.e. caught more than once, but only on a few occasions, L – low density i.e. caught during many trapping sessions, but usually only one or two captures during a session (density < 1 /ha), V – visual sighting, * – incidental capture stands (forest-like habitat). *Suncus montanus*, a shrew, was the only species captured in both habitats. The other common species in the montane forest included *Mus famulus* and *Suncus dayi*.

The total density and biomass of small mammals were highest in the old and middle-aged wattle stands. While *Rattus rattus* accounted for the bulk of the density and biomass in the old stands, *Millardia meltada* was the dominant species in the middle-aged stands. Montane forests had intermediate densities and biomass, while grasslands had relatively low density and biomass. The density and biomass of the dominant species were substantially higher in some plantations than in the natural habitats. The density of *Millardia meltada* was significantly higher in middle-aged wattle stands than in grasslands, while the density of *Rattus rattus* was significantly higher in old wattle plantations than in montane forest patches. *R. rattus* attained a maximum density of 34 animals/ha and biomass of 3.3 kg/ha in November 1995 in an old wattle plantation. *M. meltada* peaked at 31 animals/ha (1.6 kg/ha) in June 1995 in a middle-aged wattle plantation.

Seven species of rodents (Order Rodentia) and two shrews (Order Insectivora) were captured during the study period (Table 2). Two other species of rodents were sighted, but not trapped. These included the dusky striped squirrel *Funambulus sublineatus*, and the Indian giant squirrel *Ratufa indica*. The latter is a much larger species and is not relevant to the study. Kelaart's long-clawed shrew *Feroculus feroculus* Kelaart, was caught once during preliminary trapping. This marks an extension of its territory from its previously known range (Pradhan *et al.* 1997). The small mammals considered here ranged in size from 6 to 206 gm, and could in theory have weighed up to about 300 gm, based on the size of the traps used. The suborder including rats and mice is the most widespread and has the largest number of species. Compared with other rodents, members of the Family Muridae (true mice) may have evolved most recently. One hypothesis suggests that murids evolved in southern Asia, as the earliest fossils of murids have been found in Pakistan. This would have been followed by adaptive radiation to the other continents.

Rattus rattus (Linnaeus) (Muridae)

The most common and well known of murid rodents is the common rat *Rattus rattus*, also known as the black, roof, house or ship rat. *R. rattus* is found worldwide, and owes much of its ubiquity to accidental human introduction. While the brown rat *Rattus norvegicus*, has successfully colonised temperate countries, the black rat has invaded and is widespread in most tropical countries, including India. Ellerman (1961) divides the black rats broadly into two categories, the white-bellied form, which is usually found in the wild and the dark-bellied form, which is usually commensal with man; he further sub-divides them into 16 subspecies. The white-bellied form, which was trapped in many habitats in our study, was identified as *Rattus rattus wroughtoni* Hinton (Dr. M.S. Pradhan, ZSI, Pune, pers. comm.). It was trapped in natural habitats and in plantations. The dark-bellied subspecies *Rattus rattus rufescens*, which is usually found in agricultural fields, was trapped in wattle plantations. Both subspecies were trapped in the same area, raising questions about their relative taxonomic status. However, in another study, all white-bellied individuals collected from the Nilgiris were identified as *Rattus satarae* based on chromosomal, morphological and isozyme studies (Francois Catzeflis, pers. comm.). There are two separate issues here: are the different forms (subspecies) of *Rattus rattus* in fact separate species, as Catzeflis suggests? Does the *Rattus rattus* trapped in the Nilgiris belong to the species/ subspecies '*wroughtoni*' or '*satarae*'? Only extensive molecular genetic studies can provide answers to questions surrounding the taxonomy of the various forms of *Rattus rattus* found all over India.

Rattus rattus is highly arboreal in the wild. The females are territorial, while the males appear to be free ranging. Each female occupies a nest on her own and has 3-4 pups. The adult is about 15-20 cm long with a tail that is 20-25 cm long; large males weigh about 150 gm, while adult females weigh 100-120 gm. Though males rarely weighed above 150 gm, a single individual weighing 206 gm was trapped once during the study. Interestingly, the white-bellied form of *Rattus rattus* (*wroughtoni*?) was also dominant in lowland evergreen forests in the Nilgiris (Meena 1997), Anamalais (Chandrasekhar 1989; Prabhakar 1998) and Kalakkad (Divya Mudappa, pers. comm.).

Millardia meltada Gray (Muridae)

Millardia meltada, the soft-furred field rat, found in cultivated fields throughout India (Prater 1988), has adapted successfully to the grasslands of the Upper Nilgiris. The general colour is pale brownish-gray, grayish-white on the underside. It has large rounded ears and a hairy tail, has a head body length of 13-15 cm, a tail nearly as long, and weighs 50 to 70 gm. This rat is commonly found in agricultural land and lowland plantations and is a major pest in many areas in north, central and southern India.

In natural habitat that was sampled in various studies in southern India, *M. meltada* was not trapped in the mid elevation forests or plantations in Kalakkad-Mundanthurai or Anamalais and in the mid elevation forests and grasslands in Mudumalai. Its occurrence in the high altitude grasslands of the Nilgiris is therefore a matter of some interest. It is also notable that it was not found in high elevation grasslands in Aravalli hills, though it was abundant at lower elevations (Prakash *et al.*, 1995). It is possible that this species colonized the Nilgiris grassland before the advent of man about 1000 years ago, and subsequently occupied the plantations about 200 years ago. Alternatively, it may have arrived as a commensal with man and colonized the grasslands subsequently. While there has been a long standing debate on the origin of the grasslands in the Nilgiris (Bor 1938; Ranganathan 1938) recent studies indicate that it is a climax ecosystem (Sukumar *et al.* 1993; Rajagopalan *et al.* 1997). It can therefore be expected that some rodent species would have occupied this habitat. Whether *Millardia meltada* is the original colonizer or a more recent one that arrived as a commensal can only be ascertained by paleontological or molecular genetic evidence.

Weight of animals in captivity

Fifteen individuals of *Millardia meltada* were kept in captivity. Within three to seven days of capture, 4 individuals gained weight at an average of 9.3% of their body weight, 5 individuals lost weight (7.8%), and 3 showed no change in weight.

Of 17 individuals of *Rattus rattus* that were kept in captivity, 15 (88.2%) showed an increase in body weight within three to seven days. Eleven of these showed an average increase of 3.14% per day within the first week, which would lead to an increase of about 20% within a week. The maximum increase was 40% of the body weight at capture in five days.

Mus spp. (Muridae)

Bonhote's field mouse *Mus famulus* Bonhote is a small animal with a brown coat and a yellow underside. It is found at 1,507 m and above in the Nilgiris, and a few other hills in the southern Western Ghats. It is 5-8 cm long and weighs about 20 gm, and is probably less arboreal than the other rats and mice. It was found in areas of higher tree density in the forest patches (Shanker 2000b). The spiny field mouse *Mus platythrix* Bennett a species common all over India, is brownish above and white below.

Its fur is composed of flattened spines (Prater 1988). It was trapped in the two largest sholas in the first year of the study and was not trapped subsequently. Some information on the ecology of *Mus platythrix* and *Mus booduga* (Chandrahas 1974) is available; the brood of the latter has even been found in abandoned baya nests (Kichtar and Tiwari 1992)

Platacanthomys lasiurus (Muscardinidae) and other rare rodents (Muridae)

Platacanthomys lasiurus Blyth is light rufous brown above and a dull white below. The muzzle is pointed, the ears are thin and naked, and the hind feet are broad and elongated. It is 13-20 cm long and weighs about 70 gm. The spiny dormouse inhabits rocky hills and forests at altitudes of 600 m and above. It lives mainly in the cavities of trunks and branches, and in clefts in rocks. The long tail, covered with hair, serves as a balancing organ for this highly arboreal animal. This species appeared after several months of trapping in the two largest sholas, Thaishola and the 60 ha shola. It was trapped only from September to January. There is little information on the distribution of this species, however, a number of new locales have recently been documented (Rajagopalan 1968; Jayson and Christopher 1995; Prabhakar 1997). This is the only endemic small rodent in the Western Ghats, the other endemic rodents being the grizzled giant squirrel (*Ratufa macroura*) and a flying squirrel (*Petinomys fuscocapillus*).

The white-tailed wood rat *Cremnomys blanfordi* Thomas is very similar to the common rat in appearance, except for the tail, which is brown for three quarters of its length, but white towards the tip. It is highly arboreal in forests, makes a large and untidy nest, and has a litter of 2-3 young. This species was represented by a single capture in Thaishola and is probably not common at higher altitudes. It was dominant in lower elevation Deciduous Forests in Mudumalai in the Nilgiris (Meena 1997).

The long tailed tree mouse *Vandeleuria oleracea* Bennett can be distinguished by the fact that the first and fifth toe on all four feet are partially opposable and have a flat nail instead of a claw. It is about 7 cm in length, with a tail that is slightly longer. It is an extremely attractive creature, with a reddish coat and white underparts. It was trapped only once during two years of trapping in the Upper Nilgiris.

Suncus spp. (Order Insectivora, Family Soricidae)

Suncus murinus (Linnaeus), the common or grey musk shrew, is found all over India in all kinds of habitats, and is common in cities as well. It is about 10-12 cm long with a slightly shorter tail, and weighs about 20 gm. In the Nilgiris, *Suncus montanus* Kelaart, a similar looking shrew, is more common. *Suncus dayi* Dobson, a much smaller shrew, weighing just 6 to 10 gm, is also found in the Nilgiris. Shrews are highly aggressive animals and on occasions, when two shrews were caught in the same trap, one would devour the other. On one occasion, a shrew and a common rat (*Rattus rattus*) were released simultaneously from a trap, whereupon the shrew attacked the weakened rat and chewed off its ear. Shrews have been known to attack rats, and Prater (1988) suggests that presence of shrews in houses may deter rats. Saini and Parshad (1996) report the consumption of a gerbil by a shrew in a multi-catch trap. Shrews tend to die in traps as they have a high metabolic rate; also in this case, the food in the trap was usually vegetable matter such as coconut. The smaller shrew, *Suncus dayi*, was rarely captured live in the trap.

DISCUSSION

Although 'small mammals' do not constitute a taxonomic entity, the term generally includes mammals from 2 gm to 5 kg (Bourliere 1975). Of the 4,200 odd mammal species, 90%

weigh less than 5 kg. Ten out of sixteen mammalian orders contain mostly small species. In fact, both in birds and mammals, the below 1 kg class embraces the most successful order: of some 8,600 species of birds, 5,100 belong to the Order Passeriformes; of the 4,200 mammal species, about 1,700 are rodents. In India, there are about 100 species of rodents, with about 25 species in southern India. Most studies have recorded relatively few species of small mammals (three to five) in each habitat (Chandrasekhar 1989; Meena 1997; Divya Mudappa, pers. comm.). Prabhakar (1998) trapped 7 species of rodents and 1 shrew in mid-elevation rainforests. In comparison, the species richness in the high elevation montane forests of the Nilgiris is high with 6 species of rodents and 3 shrews. In addition, the grasslands had one rodent species. Trapping success (10.6%) was also high compared to studies in south India, where trapping success was 5% or lower (Chandrasekhar 1989; Meena 1997; Divya Mudappa, pers. comm.). A pattern that seems to have emerged from these studies is that mid to high elevation evergreen forest fragments support the highest species richness and abundance of small mammals in natural habitats in southern India. Another clear pattern is the dominance of the white-bellied form of *Rattus rattus* (*wroughtoni* and/or others) in evergreen habitat at mid and high elevations (this study; Chandrasekhar 1989; Meena 1997; Prabhakar 1998; Divya Mudappa, pers. comm.)

There has been a long debate on the importance of competition in structuring ecological communities (Connell 1983; Schoener 1983). The distribution of *Rattus rattus* and *Millardia meltada* in this ecosystem is particularly interesting. They are completely exclusive in the natural habitat, which is particularly notable in the shola grassland system where there is a sharp ecotone between the two habitat types. *Rattus rattus* would be found till the edge of the shola and *Millardia meltada* till the edge of the grassland, and therefore within metres of each other, but never in the other habitat. Though this initially indicated some competitive exclusion, the two species coexisted in the plantations. The distribution of the species may thus have been influenced more by the habitat parameters, trees in the case of *Rattus rattus* and grass in the case of *Millardia meltada*. This is also supported by the fact that *Millardia meltada* is dominant in young wattle stands, which have more ground cover, while *Rattus rattus* is dominant in older wattle stands with taller trees (for details, see Shanker 2000b). Removal and introduction experiments in the montane forests and grasslands did not show any competition between the species (Shanker 2000b). While the evidence for competition between the species is low, it would be interesting to carry out reciprocal removal experiments in the wattle stands where the species coexist. Gut content analysis should provide some evidence on the feeding habits of the two species. Since one is a grassland species and the other a forest species, another method of studying differences in foraging would be to look at stable carbon isotopes in bone collagen (DeNiro and Epstein 1978; Sukumar and Ramesh 1992). Food choice experiments would also shed light on their feeding habits.

Small mammals such as rodents are considered to be especially important components of the ecosystem as they serve as prey for small and medium sized carnivores. In the Upper Nilgiris, potential predators include several birds such as raptors, owls and crows and several mammals such as jungle cat, leopard cat, small Indian civet, ruddy mongoose, jackal and Nilgiri marten (listed in Shanker and Sukumar 1999). Study of the demography of small rodents in the montane patches revealed some interesting patterns. The population of *Rattus rattus* in the smaller fragments was asynchronous, which may be due to predation and demographic stochasticity (Shanker and Sukumar 1999).

Further, population characteristics of small mammals were affected by patch size (Shanker and Sukumar 1998). Apart from *Rattus rattus* and *Suncus montanus,* the other species were not trapped during all trapping sessions in the forest plots. This indicates that some of these species might periodically go extinct in the smaller patches. These would thus be a good system for the study of metapopulation biology, especially in the context of the persistence of rare species in the patch network. The shola-grassland and shola-plantation habitats also provide different kinds of landscapes to study the effects of edge permeability and habitat connectivity on small mammal populations. The results show that plantations, especially old stands, have high small mammal densities. This could affect the population dynamics of small mammals in the forest patches. These factors need to be taken into account in the management of these areas, and may be important factors to consider in the conservation of predators that depend on these small mammals for food.

The theory of island biogeography (MacArthur and Wilson 1967) was extended to isolated habitats on land with a study of mammals on mountaintops (Brown 1971). Since there are certain patterns in insular small mammal populations in the Nilgiris, similar patterns may exist in other montane ecosystems in the Western Ghats. Other studies on fragmentation in southern India have found effects of insularity and patch size on small mammal communities in lower elevation evergreen forests (Prabhakar 1998). It is possible that the patterns observed in the Nilgiris may be generalised to montane systems in the Western Ghats. It would also be interesting to look at the montane systems of various ranges as islands and examine the impact of isolation on the small mammal communities of 'mountain tops'. One could also compare the distribution of *Rattus rattus* and *Millardia meltada* in the Nilgiris with other montane ecosystems.

The relationship between population synchrony and geographical distance was not clear at smaller spatial scales. One of the ways to study population structure is through molecular genetic analysis. Populations of *Rattus rattus* from several montane forest patches and *Millardia meltada* from grasslands in the same areas were studied using multilocus minisatellite DNA fingerprinting. Patterns of inter-individual and interspecific variation in these rodent populations were examined. Inter-individual variation in *Rattus rattus* was found, which could be used in population genetic analysis (Kartik Shanker, Anindya Sinha and Trupta Purohit, unpubl. Data). More data is required before patterns of variation and population structure can be discerned. Currently, molecular tools such as microsatellite analysis are widely used for population genetic studies and can be used to answer these questions.

It is clear that much work remains to be done on small mammals in tropical ecosystems. The montane ecosystems of the Western Ghats offer a fascinating landscape where ecological hypotheses of interest can be tested. It is hoped that future generations of Indian ecologists will address some of these questions.

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THE EFFECTS OF CATTLE GRAZING AND HABITAT ON HELMINTH LOADS OF CHITAL (*AXIS AXIS*) IN THE MUDUMALAI WILDLIFE SANCTUARY, SOUTHERN INDIA[1]

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Key words: cattle, chital, *Axis axis*, helminth loads, habitat

Coprological estimation of helminth eggs per gram of faeces (epg) was used as an index to study how habitat and sympatric grazing by cattle affect helminth loads in chital (*Axis axis*) at the Mudumalai Wildlife Sanctuary, Tamil Nadu. Two distinct groups of chital were sampled, fortnightly, in Dry Deciduous forest (DDF) and Scrub forest (SF), one in areas with sympatric cattle grazing and the other in areas without cattle. The median helminth load (MHL) of chital in DDF without cattle (2 epg) and SF without cattle (1 epg) showed no significant difference ($p>0.05$). However, the MHL of chital in DDF with cattle grazing (2 epg) and SF with cattle grazing (4 epg) differed significantly ($p<0.05$). Chital in DDF with or without sympatric cattle had MHLs of 2 epg ($p>0.05$). However, the MHL of chital in SF with sympatric cattle grazing (4 epg) and without cattle grazing (1 epg) showed a significant difference ($p<0.05$). It is hypothesized that in nutrient-poor scrub areas where chital are further subjected to resource competition by cattle, nutrient levels may be lowered, making chital increasingly susceptible to either their own parasites or to those of cattle.

INTRODUCTION

In India there is increasing human pressure on protected areas, one manifestation is the growing domestic-wild animal interface and its resultant — increased chances of interspecific transmission of disease. Endangered wildlife populations are usually protected from virulent pathogens because they are usually well below the threshold population size (H_T) (Lyles and Dobson 1993). However, this may not be the case when wild and domestic animals share both pasture and pathogens. In this study, we examined the effects of both cattle and habitat upon parasitic worm loads in chital (*Axis axis*). We used a quantitative estimate of the number of propagules (eggs or larvae) in the host faeces as an index of parasite loads in the host. Egg output is considered to be an accurate indicator of parasite biomass because of its positive correlation with worm size and number (Skorping *et al.* 1991). Though this method has limitations (Foreyt and Trainer 1980), being non-invasive it is useful in wildlife.

STUDY AREA

Mudumalai Wildlife Sanctuary and National Park, and Sigur Reserve Forest (11° 32'- 11° 93' N and 76° 22'- 76° 43' E) have elevations between 900-1000 m above msl. A high diversity of vegetation types has been observed (Sukumar *et al.* 1992). There is a rainfall gradient from the western side (1,800 mm/year) which is characterized by Moist and Dry Deciduous Forests (DDF) to the eastern side (600 mm/year) composed mainly of Dry Thorn or Scrub Forest (SF).

MATERIAL AND METHODS

Hosts sampled

Cattle and chital were sampled between 0700 and 0900 hrs at fortnightly intervals, from May to late July, 1999. As the maximum linear

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distance between sightings of individual chital is only 2 km (Barette 1991) they could be divided into non-overlapping groups:

1. Chital in Dry Deciduous Forest areas with sympatric cattle grazing.
2. Chital in Dry Deciduous Forest areas without sympatric cattle grazing.
3. Chital in Scrub Forest areas with sympatric cattle grazing.
4. Chital in Scrub Forest areas without sympatric cattle grazing.

Since the same cattle grazed in both Dry Deciduous and Scrub Forest areas, samples collected from cattle in different habitat types had to be pooled.

Coprological study

A representative sample (approx. 2 gm) was collected from distinct, fresh dung piles in labeled, pre-weighed containers with 10 ml of 10% formalin. The exact weight of faeces was calculated by subtracting the weight of the container and formalin from the final weight. The intensity of helminth infection was determined by the quantitative Sedimentation–Flotation Technique of Watve (1992).

Terminology

Helminth loads are expressed in terms of eggs per gram of faeces (epg). We use the term to include lungworm larvae. Due to the methodology used, definitions of some terms differ from Margolis *et al.* (1982). 'Prevalence' indicates the percentage of samples positive for helminth eggs or larvae. 'Sympatric' is defined as: (of biological speciation or species) taking place or existing in the same or overlapping geographic areas (Hanks 1979).

Statistical Analyses

Calculation of index of dispersion, d-statistic and fitting of the negative binomial distribution has been done as per Ludwig and Reynolds (1988). Green's index was calculated as per Green (1966). The Mann-Whitney Test was performed as per Conover (1971).

RESULT AND DISCUSSION

The negative binomial distribution gave good fits to observed data in cattle and all four sub-populations of chital (Table 1). The d-statistic being > 1.96 (Table 1), a clumped parasite distribution is hypothesized (Ludwig and Reynolds 1988), implying that a few hosts harbour many helminths, while many hosts have few or none (Waid *et al.* 1985).

Comparison of the median helminth loads between the four groups of chital are reported in Table 2. The median was used in preference to the mean since the data are non-normally distributed. The median helminth loads of chital in Dry Deciduous Forest areas without cattle grazing (2 epg) and Scrub Forest without cattle grazing (1 epg) showed no significant difference ($p>0.05$). Similarly comparison of chital in Dry Deciduous areas with sympatric cattle grazing and without cattle grazing showed that both had median helminth loads of 2 epg ($p>0.05$). However, the median helminth loads of chital in Dry Deciduous Forest areas with cattle grazing (2 epg) and Scrub Forest with cattle grazing (4 epg) differed significantly ($p<0.05$). And, the median helminth loads of chital in scrub forest areas with sympatric cattle grazing (4 epg) and those without cattle grazing (1 epg) showed a significant difference ($p<0.05$). It is thus clear that neither forest type nor cattle grazing affects helminth loads in chital if they act independent of each other. However, helminth loads in chital increase dramatically when they are sympatric with cattle in scrub forest. Since immunocompetence is affected by nutrition (Rolston 1992; Lyles and Dobson 1993), it is likely that chital in scrub forest with sympatric cattle grazing have high helminth loads due to increased competition with cattle for limited forage resources.

Table 1: Distribution of helminth eggs in chital sub-populations and domestic cattle at the Mudumalai Wildlife Sanctuary, Tamil Nadu

Host Population	Sample size (n)	Prevalence (%)	Helminth load (epg)		Indices of dispersion			NBD characteristics		
			Mean	Variance	Variance mean ratio	d-statistic	Green's Index	k	χ^2	p
Chital in SF with cattle	55	80.00	5.64	106.16	18.84	34.76*	0.058	0.752	11.7^{ns}	>0.1
Chital in SF without cattle	39	69.23	2.00	18.68	9.34	18.00*	0.108	1.205	3.81^{ns}	>0.5
Chital in DDF with cattle	60	78.33	2.95	54.01	18.31	35.67*	0.098	1.28	9.11^{ns}	>0.5
Chital in DDF without cattle	60	70.00	2.4	48.38	20.16	37.96*	0.133	0.963	9.71^{ns}	>0.1
Cattle in SF & DDF	56	91.07	7.84	156.35	19.95	36.40*	0.043	1.19	12.5^{ns}	>0.1

SF- Scrub Forest; DDF- Dry Deciduous Forest; epg-eggs per gram of faeces; NBD- Negative Binomial Distribution;
*- Statistically Significant (in case of d-statistic :d >1.96); ns- not significant at 5%level.

Chital in Scrub may get less nutritional resources than those in the Dry Deciduous for three reasons: differences in the primary productivity of the two areas, vegetation differences between the habitats and the time period of our study. In general, low-rainfall scrub areas have a lower primary productivity than the moderate to high rainfall Dry Deciduous Forests (Sukumar 1992). This is because of an almost linear relationship between net primary productivity and precipitation (Whittaker 1970). Secondly, while the Dry Deciduous Forests has higher levels of browse (Sukumar, 1992), Scrub habitat in Mudumalai is dominated by grass with little browse available, especially for the smaller herbivores. But most important was the time during which we sampled the chital populations. The first rainy season in Mudumalai usually begins in mid-May (N. Baskaran, pers. comm.). However, in 1999, the first rains were delayed to mid-June. Thus over half our samples were collected during the late dry season, when the grass is likely to have the least nutritive value (Sukumar 1990). However, grass does not always have low nutritive value and Ekaya (2001) found that the nutritive value was high during the short period of flush during the growing season. This growing season corresponds with the beginning of the rains in Mudumalai, and the high nutritive value of the grass is the reason why the more mobile species of wild herbivores, like elephants, prefer Scrub to Dry Deciduous Forests just after the rains (Sukumar 1990). Similarly, and in light of the arguments given previously, we found that chital in the scrub forest areas with cattle grazing began to show a significant downward trend in helminth loads as the wet season progressed, though they still remained higher than the other sub-groups of chital. This was likely because of improved nutritional status, due to increased availability of grass with high nutritional value. Similar downward trends were not observed for the other sub-groups of chital or other herbivore species examined. These results have been reported elsewhere (Dharmarajan 2000; Dharmarajan and John 2001).

Sympatric cattle are likely to further reduce the availability of forage resources for chital. In large numbers, cattle tend to overgraze and cause outflow of nutrients from an ecosystem (Singer and Boyce 1996). Cattle grazing can increase the helminth loads in other ways too. First, due to a decrease in nutrient levels, the deer may roam larger areas and graze for longer periods to obtain adequate nutrition, which would increase chances of contact with infective stages of parasites (Gordon 1948). Secondly, overgrazing and trampling by cattle will reduce the height of the grass and leave more open ground, thus increasing contact with infective stages (Kauzal 1941; Gordon 1948). Thirdly, chital in the scrub areas grazed by cattle are under great stress (nutritional, heat, etc.) which reduces resistance to disease (Fowler 1986).

The reduced nutritional levels of chital in Scrub with sympatric cattle could increase helminth loads either by increasing the susceptibility of chital to their own parasites or to cattle parasites. Our data shows that the latter is more likely to be the case in Mudumalai (Dharmarajan *et al.* in press.).

Another finding supporting the view that cattle adversely affect chital from a parasitological point of view is that poor nutrient habitat on its own is not responsible for increased helminth loads. We find that helminth loads of chital in Dry Deciduous Forest without sympatric cattle do not differ significantly from those of chital in Scrub without sympatric cattle (Table 2). This may be because under "natural conditions" (i.e. absence of domestic cattle grazing) there is a balance between host and parasite (Gordon 1948) and in general, worm burdens do not become intolerable. Additionally, factors that contribute to poor nutrition of the host, like low moisture and vegetation cover, will adversely affect survivability of infective helminth larvae (Stromberg 1997). In such an

Table 2: Comparison of median helminth loads between four chital sub-populations using the Mann-Whitney U Test at the Mudumalai Wildlife Sanctuary, Tamil Nadu

Chital Populations compared pair wise		Median (epg)		Sample size		T_1	Implication
Population 1 (X)	Population 2 (Y)	X	Y	n	m		
Overall SF (With and Without Cattle)	Overall DDF (With & Without Cattle)	2	2	94	120	0.903^{ns}	No significant difference between the helminth loads of the two populations
SF (With Cattle)	DDF (With Cattle)	4	2	55	60	1.95 *	Helminth loads significantly higher in SF with cattle compared to DDF with cattle
SF (Without Cattle)	DDF (Without Cattle)	1	2	39	60	1.103^{ns}	No significant difference between the helminth loads of the two populations
Areas with cattle (SF & DDF)	Areas Without Cattle (SF & DDF)	2	2	115	99	2.7 *	Helminth loads significantly higher in areas with cattle than those without cattle
DDF (With Cattle)	DDF (Without Cattle)	2	2	60	60	0.64^{ns}	No significant difference between the helminth loads of the two populations
SF (With Cattle)	SF (Without Cattle)	4	1	39	55	3.09 *	Helminth loads significantly higher in SF with cattle than in SF without cattle

SF = Scrub forest; DDF = Dry deciduous forest; epg = eggs per gram of faeces; n = Number of Samples from Population 1; m = Number of Samples from Population 2; T_1 = Mann-Whitney test statistic; ns = not significant at 5% level; * = significant at 5% level.

unfavourable macro-environment, larval survival is greater in dung pats compared to pellets, because while pellets are generally dry, dung pats contain high amount of moisture (Soulsby 1968). Additionally, due to the formation of a hard, dry outer layer, the interior of dung pats retain moisture for long periods of time. Thus, larvae in cattle dung pats are likely to have improved survival as compared to those in chital pellets. This in turn could adversely affect helminth loads in chital, because chital under nutrient stress are likely to be susceptible to cattle parasites (Dharmarajan *et al.* in press).

In conclusion, the increased loads in chital in scrub forest areas with sympatric cattle grazing is probably due to the interactive effect of poor habitat and inter-specific competition for limited resources. The finding that cattle may have an adverse effect on chital, from a parasitological perspective, in resource-poor and/or degraded habitats should be an issue of concern to conservationists. Though the present work was restricted to chital, cattle may have similar adverse effects on other wild herbivores in and around Mudumalai Sanctuary. More detailed work is required to get a clearer picture of the effects of cattle on wild herbivores, from a physiological and pathological perspective, especially in terms of diseases caused by more serious pathogens like viruses and bacteria.

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DEMOGRAPHY OF LIONTAILED MACAQUE (*MACACA SILENUS*) IN AN UNDISTURBED RAINFOREST OF SILENT VALLEY NATIONAL PARK, KERALA, INDIA[1]

(*With two text-figures*)

GIGI K. JOSEPH[2, 3] AND K.K. RAMACHANDRAN[2, 4]

Key words: *Macaca silenus*, demography, birth rate, survival rate, growth rate, sex ratio

The demography of the liontailed macaque (*Macaca silenus*) was studied in the Silent Valley National Park and its adjacent areas from 1993 to 1996. Birth rate, survival rate and growth rate were estimated by methods described by earlier authors (Caughley 1977, NRC 1981). Fourteen troops with 275 individuals were observed. The adult male:female sex ratio was 1:5.6. A low birth rate (0.22/adult female/year) and a high survival rate (0.98/individual/year) were the noteworthy features of the population. Birth rate decreased as the troop size and number of adult females increased. A marginal increase in growth rate was observed. The study provides estimates of population parameters of the endangered liontailed macaque in an undisturbed and contiguous rainforest for the first time.

INTRODUCTION

Factors such as habitat fragmentation, reduced habitat area, isolation of populations leading to inbreeding depression and vulnerability to random events make the liontailed macaque a highly endangered species (Kumar *et al.* 1995, Easa *et al.* 1997). Therefore, demographic studies of this species deserve utmost importance.

The Silent Valley in Kerala and Ashambu hills in Tamil Nadu are perhaps the only two viable habitats left for these macaques (Green and Minkowski 1977, Ramachandran 1990, Joseph 1998, Joseph and Ramachandran 1998). The demography of this macaque has been studied in fragmented forests in Anamalai hills, Tamil Nadu (Kumar 1987). Recently, Umapathy and Kumar (2000) reported the occurrence and abundance of liontailed macaque in 25 rain forest fragments in the Anamalai hills in relation to several ecological factors. However, no long-term demographic studies have been attempted so far in any of the large contiguous habitats. The present study was conducted in order to estimate the demographic parameters such as troop composition, birth rate, survival rate and growth rate of this primate in the undisturbed rainforest ecosystem in Silent Valley, and to compare them with those obtained from Anamalai hills (Kumar 1987).

STUDY AREA

The Silent Valley National Park is situated in Palakkad district, Kerala State (11° 3' to 11° 13' N; 76° 21' to 76° 35' E). It is one of the core areas of the Nilgiri Biosphere Reserve. The total area of the Park is 90 sq. km and it is contiguous with Attappady Reserve Forest in the east, Mukkurthi National Park in the north, Nilambur forest division in the west and Mannarkkad forest division in the south (Fig. 1). Kunthipuzha, a tributary of Bharathapuzha, originating from the northeastern hill ranges of the Park, drains the area. The altitude varies from 658 to 2,383 m and the terrain is quite undulating. Silent Valley is one of the highest rainfall areas in the Western Ghats, with an annual rainfall of about 6,000 mm. The annual mean temperature is around 20 °C. The major vegetation is of Tropical Wet Evergreen type.

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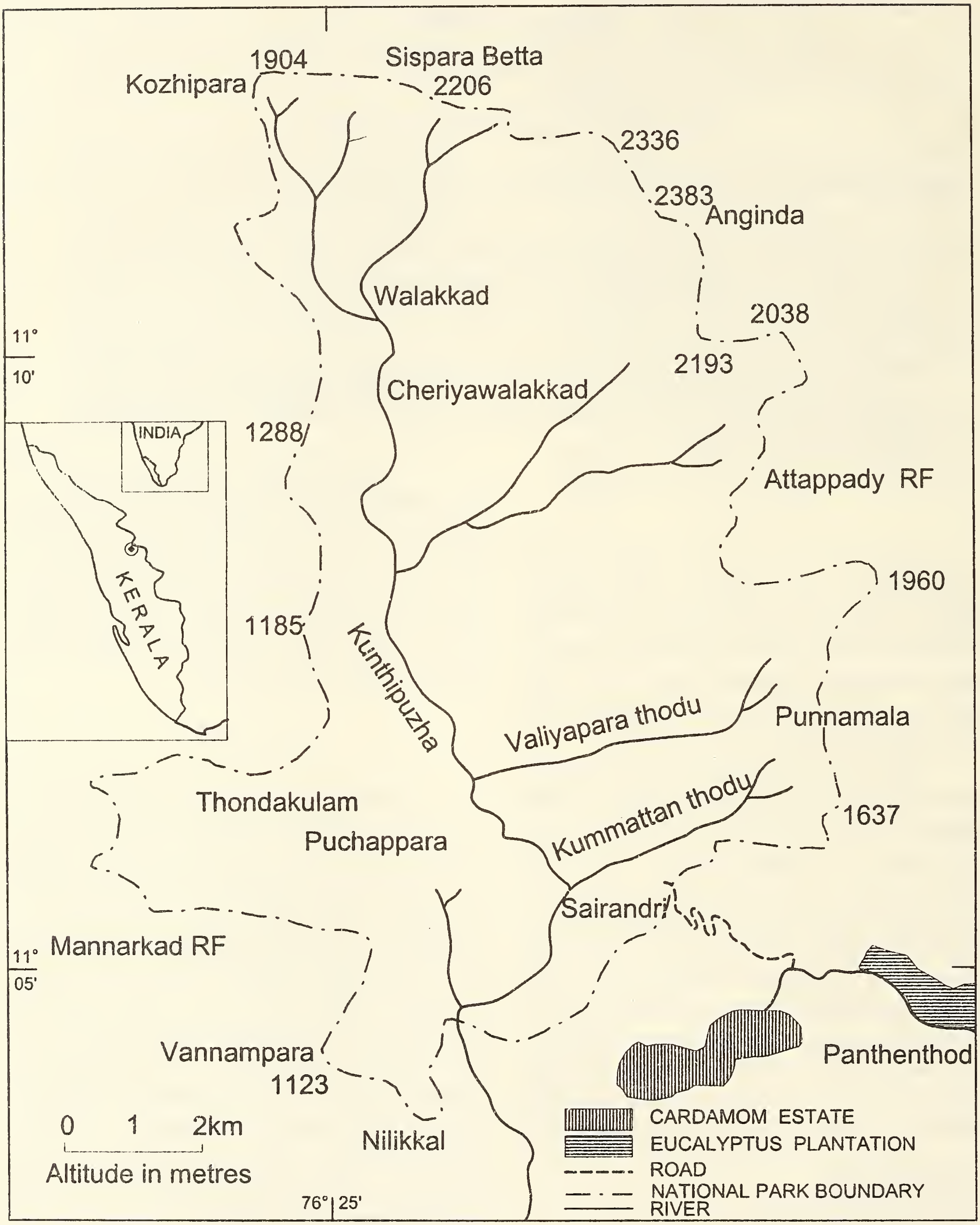
1904
Sispara Betta
Kozhipara
2206
2336
2383
Anginda
Walakkad
2038
11°
10'
2193
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INDIA
1288
KERALA
Attappady RF
1960
1185
Kunthipuzha
Valiyapara thodu
Punnamala
Kummattan thodu
Thondakulam
1637
Puchappara
Sairandri
11°
05'
Mannarkad RF
Panthenthod
Vannampara
1123
0 1 2km
Altitude in metres
Nilikkal
76° 25'
CARDAMOM ESTATE
EUCALYPTUS PLANTATION
ROAD
NATIONAL PARK BOUNDARY
RIVER

Fig. 1: Silent Valley National Park and adjacent areas

METHODS

The demography of the liontailed macaque was studied in Silent Valley National Park and adjacent areas for three years from 1993 to 1996. The primate population was estimated by total count and sweep sampling methods (NRC 1981, Whitesides *et al.* 1988). Census surveys were made on foot, radiating from the four wireless stations (Sairandri, Nilikkal, Puchappara and Walakkad) situated inside the Park. Frequent stops were made to get the characteristic contact call of the liontailed macaque. The intermittent contact calls are audible up to 100 m. The troops located were followed until each troop was reliably counted or till it could not be followed.

Poor visibility due to the closed canopy and highly undulating terrain, with intermittent inaccessible areas, were the major limitations in population count. Moreover, the foraging sub units or consort pairs were often far away from the troop. Several times, the survey was terminated due to the presence of elephant herds, continuous rain and mist. Complete counts were easy when the troop passed over a stream, path or some temporary gaps in the canopy. When minor differences occurred between successive counts, the larger number was taken as true.

Animals were classified into four age-sex classes based on their morphological differences: adult male, adult female, subadult male and immature. Adult males were identified by their stouter body, long canines and large tail tufts. Adult females were identified by their elongated nipples and baggy breasts. Less developed musculature and comparatively shorter canines indicated subadult males. Other individuals were classified as immature.

A total of nine troops were identified in 1993, of which seven (Sairandri, Aruvampara, Punnamala I, Parathod, Puchappara, Chembotty I and Nilikkal I) were inside the National Park and two in the adjoining Panthenthod beat of the Attappady Reserve Forest (Panthenthod I and Panthenthod II). Two more troops (Nilikkal II and Chembotty II) were identified in 1994 and one (Punnamala II) in 1995. Fission occurred in two troops (Aruvampara and Chembotty I) during 1995 resulting in four troops (Aruvampara I and Aruvampara II, Chembotty IA and Chembotty IB). All the troops were monitored once a year up to 1996.

Disappearance of an animal between consecutive censuses was considered as a death. Recruitment to the troop was carefully tallied, considering the disappearances. A black eagle (*Ictinaetus malayensis*) preyed upon an immature from the Sairandri troop in 1995. An incident of poaching by Muduga tribals occurred in one troop (Panthenthod II). This troop was excluded from analysis. The newly formed troops after fission could be counted only once and were also excluded from analysis. Thus, data for analysis of population parameters such as birth rate, survival rate and growth rate, were taken only from 11 troops.

Birth rate is estimated as the proportion of females giving birth in a year, out of the total number of adult females under observation (Caughley 1977, Kumar 1987). Survival rate was estimated as the proportion of individuals that survived in the observed year out of the total number of individuals under observation. Per capita rate of increase or finite rate of increase λ is a simple measure of population growth rate and was calculated as:

$$\lambda = N_t + 1 / N_t$$

where N_t is the number of individuals in a population at time t. When λ is greater than one, the population has increased in the period t to t+1. When λ is less than one, the population has decreased, and when λ = 1, the population size has remained constant (NRC 1981).

RESULTS

Troop composition

Fourteen distinct troops with a total of 275 individuals were identified from Silent Valley and

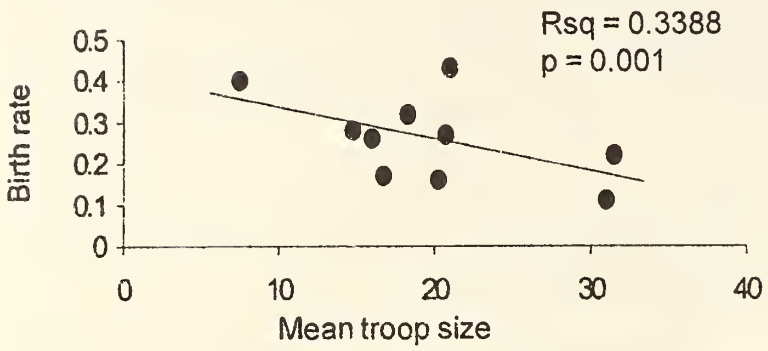

Fig. 2a: Mean birth rate during 1993-96

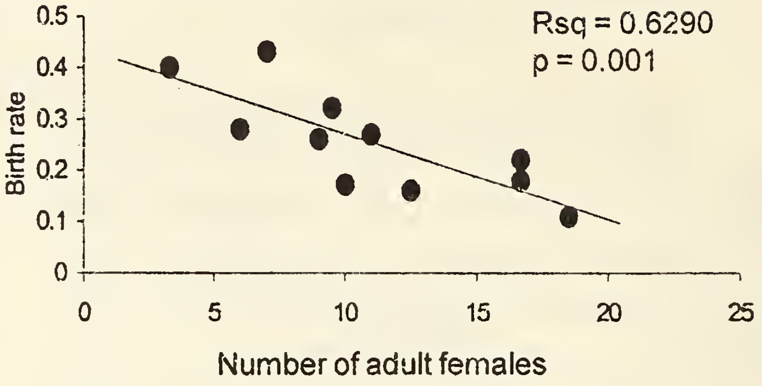

Fig. 2b: Mean birth rate of adult females in a troop during 1993-96

adjacent areas, when the field study ended in 1996 (Table 1). The troop size ranged from 9 to 36 individuals, with an average of 19.64 individuals (s.e. = 0.982). All troops together constituted 8% adult males, 45% adult females, 6% subadult males and 41% immatures. The adult male:female sex ratio ranged from 1:3.5 to 1:8.5 with a mean of 1:5.64 (s.e. = 0.282).

Birth rate

A total of 295 adult female-years were monitored to estimate the birth rate during 1993-1996. A total of 64 infants were born in 11 troops, giving a birth rate of 0.22/adult female/year. Mean birth rate was higher in 1994-95 and 1995-96 (0.23/adult female/year) than in 1993-94 (0.18/adult female/year). Birth rate decreased when the troop size increased (Fig. 2a). Birth rate also showed high negative correlation with the number of adult females (Fig. 2b). The Chembotty I troop had the greatest number of adult females and the lowest birth rate (0.11/adult female/year).

Survival rate

Table 2 shows the survival rate of all age/sex classes together in 11 troops giving survival rate of 0.98/individual/year. Fourteen disappearances were recorded in the study period and these included eight adult females, three immature individuals, one adult male and two subadult males. The highest survival rate (0.99/individual/year) was recorded for Nilikkal I troop, in which only one disappearance occurred

Table 1: Status of lion-tailed macaque troops in Silent Valley National Park and adjacent areas

Sl. No	Troop name	Adult male	Subadult male	Adult female	Immature	Total
1	Sairandri	2	3	16	13	34
2	Punnamala I	2	2	10	6	20
3	Punnamala II	1	1	7	12	21
4	Panthenthod I	2	1	9	8	20
5	Panthenthod II	1	1	6	8	16
6	Aruvampara I	1	2	7	4	14
7	Aruvampara II	1	0	5	7	13
8	Parathod	1	0	4	4	9
9	Puchappara	1	1	6	8	16
10	Chembotty IA	2	1	7	6	16
11	Chembotty IB	2	1	10	7	20
12	Chembotty II	2	1	11	7	21
13	Nilikkal I	2	3	17	14	36
14	Nilikkal II	2	0	9	8	19
Total		22	17	124	112	275

Table 2: Survival rate of all the age/sex classes for each troop

Troop Name	Number of years monitored	Total animal years monitored	Deaths recorded	Survival rate
Sairandri	3	94	3	0.97
Punnamala I	3	52	0	—
Punnamala II	1	21	1	0.95
Panthenthod I	3	49	0	—
Aruvampara	2	42	1	0.98
Parathod	3	22	1	0.95
Puchappara	3	47	0	—
Chembotty I	2	63	2	0.97
Chembotty II	2	42	3	0.93
Nilikkal I	3	97	1	0.99
Nilikkal II	2	36	2	0.94
Total	27	565	14	0.98

during the study period. The survival rate was lowest (0.93/individual/year) in Chembotty II troop, in which three deaths or disappearances were recorded.

Growth rate

The data for the estimation of per capita growth rate was taken from 11 troops. Table 3 shows the rate of growth recorded in different troops in each year. The highest mean growth rate (1.12/individual/year) was noticed in 1995 and the least (1.07/individual/year) in 1996. The mean growth rate over the study period was 1.09/individual/year. There was considerable variation in the growth rate among different troops. The highest mean growth rate was estimated in Panthenthod I troop (1.19/individual/year). Out of the eight troops monitored in 1994, the highest mean growth rate was in the Puchappara troop (1.25/individual/year). Ten troops were monitored in 1995, and the highest increase was recorded in Panthenthod troop (1.29/individual/year). Out of the nine troops monitored in 1996, there was no increase in four troops and the highest rate of increase was recorded in Punnamala I troop (1.18/individual/year).

Table 3: Per capita rate of growth in various liontailed macaque troops

Troop name	Per capita rate of growth			
	1994	1995	1996	Mean
Sairandri	1.00	1.07	1.10	1.06
Punnamala I	1.00	1.13	1.18	1.10
Punnamala II	nd	nd	1.00	1.00
Panthenthod I	1.17	1.29	1.11	1.19
Aruvampara	1.00	1.10	nd	1.05
Parathod	1.17	1.14	1.13	1.15
Puchappara	1.25	1.07	1.00	1.11
Chembotty I	1.07	1.06	nd	1.07
Chembotty II	nd	1.11	1.00	1.06
Nilikkal I	1.07	1.07	1.13	1.09
Nilikkal II	nd	1.12	1.00	1.06
Mean	1.09	1.12	1.07	1.09

nd = no data

DISCUSSION

Successive monitoring of demographic variables provides the best means of assessing the status of a population and the effectiveness of management (Kyes *et al.* 1998). In the Western Ghats, the liontailed macaque is present in small populations due to extensive fragmentation of the rainforest habitat. Such small populations often undergo random shifts in size due to natural events or human influence, and can lead even to local extinction. Out of the total wild population of nearly 4,000 liontailed macaques, the Kerala part of Western Ghats holds more than 50%, while the rest is shared between the states of Karnataka and Tamil Nadu (Kumar *et al.* 1995). The present study indicates that the Silent Valley National Park population, with at least 14 troops and 275 individuals, is one of the most important populations in its entire range of distribution. This population is part of a larger population in the 400 sq. km of rainforest nearby in Attappady, Silent Valley, New Amarambalam area.

The liontailed macaque forms relatively small troops compared to other macaques, most of which have a mean troop size between 20 and

30 individuals (Caldecott 1986). Kumar (1987) monitored 10 liontailed macaque troops in the Anamalai hills and estimated a mean troop size of 19.9 individuals. The present study also revealed an average troop size of 19.64 individuals, with a range of 9 to 36 individuals.

The adult male:female ratio is consistently less than 3 females per male in the genus *Macaca*, except for the pig-tailed macaque (*Macaca nemestrina*) and liontailed macaque (Caldecott 1986, Kumar 1987). In *M. nemestrina*, the adult sex ratio goes up to 8.0 (Caldecott 1986). Kumar (1987) reported a mean adult sex ratio of 5.6 for liontailed macaque population in the wild. The present study closely agrees with the latter in having the mean adult sex ratio as 5.67 females per male.

The remarkably high age at first birth and low birth rate as compared to other macaques, is characteristic of the liontailed macaque. Even though in most of the macaques the age at first birth is between 40 to 60 months, the lion-tailed macaque stands out with 80 months. The birth rate is also very low (0.28) in Anamalai hills (Kumar 1987), and 0.23 in this study. The low birth rate in Silent Valley population may be due to the presence of many large troops with greater numbers of females. In large troops with more adult females, fewer females show sexual swelling due to increased competition for food resources (Kumar 2000). When Kumar (2000) compared two group size classes of lion-tailed macaque, more births occurred in the small group size classes indicating the relation between the group size and birth rate.

According to Kumar (1987), the high survival rate is a characteristic feature of the liontailed macaque. The present study corroborates his finding, in that the mean survival rate of different troops in Silent Valley is as high as 0.98/individual/year. The high rate of immature survival clearly shows increased investment, e.g. vigilance of adults over immatures. Various birds of prey like black eagle (*Ictinaetus malayensis*) and crested serpent eagle (*Spilornis cheela*) are considered the most important predators of immature liontailed macaque. Tigers and leopards also occasionally prey on them. Adults very often sense the presence of these predators and give alarm calls.

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NEW DESCRIPTIONS

A NEW HUMAN BLOOD FEEDING BITING MIDGE FROM INDIA, DIPTERA: CERATOPOGONIDAE: *FORCIPOMYIA MANASI*[1]

(*With three text-figures*)

Girish Maheshwari[2]

Key words: *Forcipomyia manasi* sp. nov., vector, human

Forcipomyia manasi sp. nov. was collected from the body of Mr. H.R. Sou, a research scholar, while it was feeding on his blood. Host-specificity of the biting midge was further confirmed by the Precipitin Method. Mouth parts and feeding behaviour were found to resemble species of *Culicoides*, which feed on human blood.

INTRODUCTION

Biting midges are vectors of numerous viral, protozoan and helminth pathogens. A number of viruses have been isolated from biting midges, namely the Simbu, Orbivirus, Rhabdovirus and Oropouche groups and specially the *Culicoides* species. The proven association of biting midges with transmission of Oropouche virus in man has now elevated the medical importance of biting midges.

About a hundred species of *Forcipomyia* are reported from the world, of which seventeen are found in India (Borkent and Wirth 1997). The host-specificity of *Forcipomyia* is not very well studied and only a few species are reported feeders on frogs and birds. *Forcipomyia manasi* is perhaps the first record of Forcipomyian biting midges feeding on human blood.

MATERIAL AND METHODS

A wild population of *Forcipomyia manasi* has been used in the present investigation. Fed females of the species were collected from the field, and the Precipitin Method was used to assess the preliminary host-specificity. The material was prepared for taxonomic studies by the following method adopted by the School of Entomology, St. John's College, Agra, India. Adults were preserved in 70% ethanol and in 4% aqueous solution of formaldehyde (preserves coloration better than alcohol). Before dissection, the material was cleaned in cold KOH (10% solution in water) and 2-propanol. Volsella of male genitalia was removed and mounted separately under a cover slip in lateral view. The genitalia were first mounted laterally in Canada balsam and the shape of the apicolateral process was noted. The male specimen was then reoriented to a dorsoventral position, and females to ventrolateral position. The terminology of Boorman (1990) and Wirth and Messersmith (1971) have been followed.

TAXONOMIC DESCRIPTION

Forcipomyia manasi sp. nov.

Female imago: Length: 1.44 mm. Wing length: 0.75 mm, width 0.35 mm.

Antenna: (Fig. 1a): Scape well-developed, with 8-10 setae; pedicel rounded, width more than length, with 6-7 setae. Flagellum with 13 flagellomeres; flagellomeres 1 to 8 beaded, 1st and 8th subequal, 2-7 wider than long, 9-13 elongated, ultimate flagellomere longest with distinct pointed tip. Length, width of pedicel (mm) 0.030, 0.050. Length, width of

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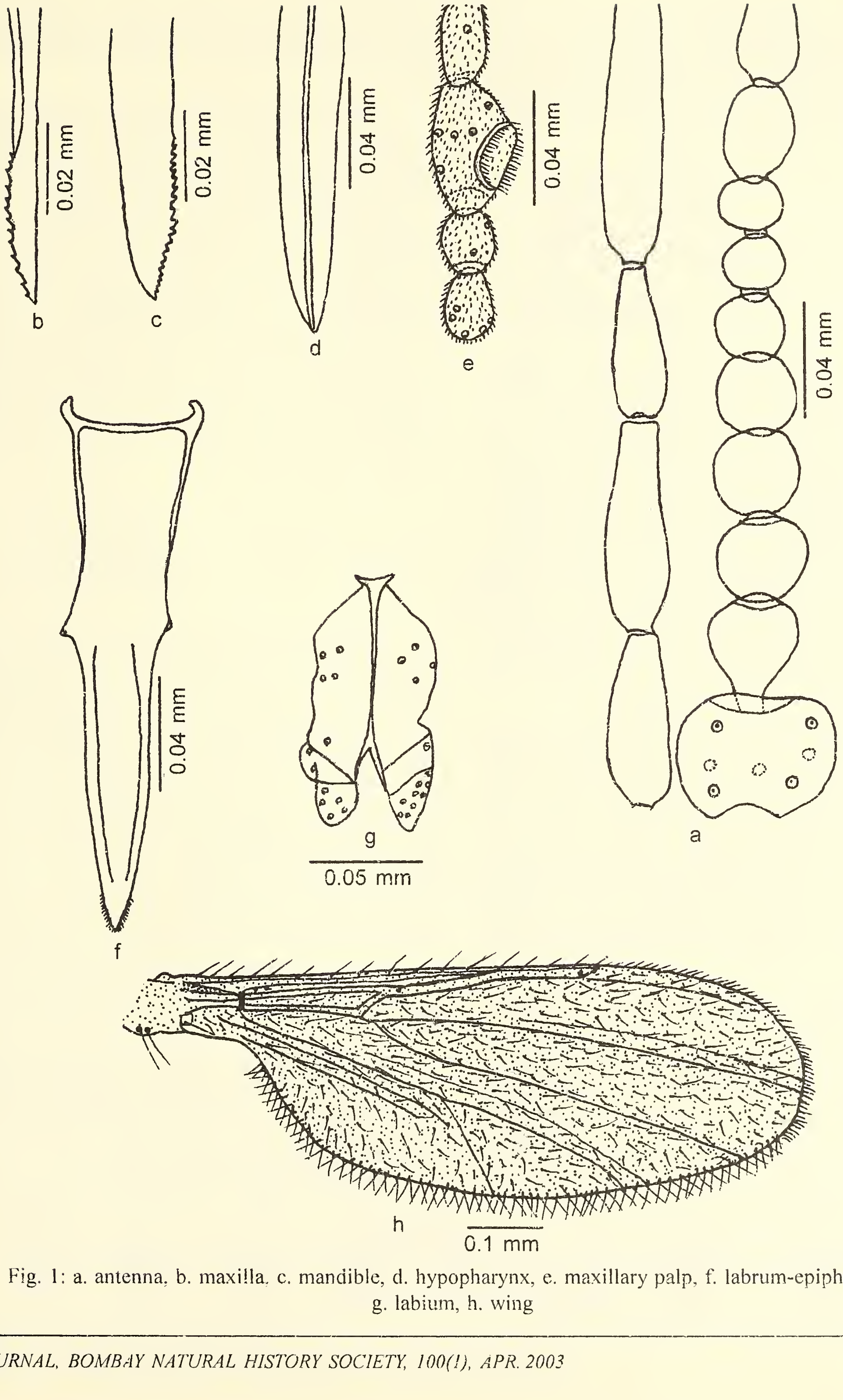
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Fig. 1: a. antenna, b. maxilla, c. mandible, d. hypopharynx, e. maxillary palp, f. labrum-epipharynx, g. labium, h. wing

flagellomeres (mm) 0.024, 0.024; 0.013, 0.022; 0.015, 0.021; 0.015, 0.021; 0.015, 0.019; 0.015, 0.018; 0.015, 0.018; 0.018, 0.018; 0.044, 0.016; 0.047, 0.015; 0.052, 0.015; 0.055, 0.015; 0.079, 0.014. AR* = 2.08.

$$\text{*AR (Antennal Ratio)} = \frac{\text{Terminal elongated flagellomere}}{\text{Rest of the basal flagellomeres}}$$

Head: Coronal suture absent, frontal tubercle present. Temporal setae numerous. Eyes bare, narrowly separated by small bridge, ommatidia moderate. Clypeus broader than long, U-shaped, with 10 setae. Length, width of clypeus (mm) 0.048, 0.079. Maxillary palp (Fig. le) with five palpomeres, of which third and fourth are ovoid, the former elongated with a large pit bearing capitate sensilla. Length, width of palpomeres (mm) 0.012, 0.009; 0.024, 0.012; 0.036, 0.020; 0.017, 0.0141, and 0.021, 0.012 and setae 2, 2, 5, 3, 5, respectively.

Proboscis with well-developed cibarial pump and upwardly directed cornua. Mandible (Fig. 1c) strong, serrated with 20-22 small teeth; maxilla (Fig. 1b) scalpel-shaped with 15-17 backwardly directed teeth. Labrum-epipharynx (Fig. 1f) sclerotized apically with pointed hypopharynx (Fig. 1d); labium (Fig. 1g) setose and flappy. Mouth parts adapted for blood-sucking.

Thorax: Humeral pit and parapsidal suture absent. Antepronotum with 5 setae. Acrostichals and dorsocentralis numerous, scattered, not arranged in rows. Scutellum with two rows of scutellars, mid scutellum bears 8-9 large setae, and lateral with 7-8 small setae. Anapleural suture present; pre-episternals absent. Postnotum bare.

Wing (Fig. 1h): Light brown; costa large, ending before 2/3 the wing. Radial sector large, densely covered with macrotrichia. First radial cell obliterated, second radial cell compact, R_{4-5} proximally with light pigmentation, false veins M_1 and M_{3+4} present. Media bifurcates distal to cross vein r-m. Wing densely covered with fine macrotrichia; microtrichia present on wing membrane. Brachiolum with 28-30 sensilla campaniformia, Radial sector with 3 sensilla campaniformia, Subcosta with two at wing base. Alula without macrotrichia; squama with two elongate setae. CR* = 0.64.

$$\text{*CR (Costal Ratio)} = \frac{\text{Length of costa}}{\text{Total length of wing}}$$

Legs (Fig. 2i-m): Femora and tibia slightly swollen; fore and hind tibial spurs present, lengths (mm) 0.048, 0.032 respectively; mid tibial spur absent; width at the apex of fore, mid and hind tibia (mm) 0.036, 0.028, 0.028 respectively. Fore tibial comb absent; 5-7 elongated setae present at the apex; hind tibial apex with two combs; first comb with 8 large spines; third spine longest; second comb with 13 small spines. Pseudospurs and palisade setae present on first four tarsomeres; ultimate tarsomere with a pair of markedly curved claws and an empodium. Length and proportions of legs as in Table 1.

Genitalia (Fig. 2n & 3o): Alimentary canal filled with blood. Spermatheca single, circular; spermathecal neck absent. Coxasternapodeme

Table 1: *Forcipomyia manasi* sp. nov., female: lengths (mm) and proportions of legs

Legs	Fe	Ti	Ta_1	Ta_2	Ta_3	Ta_4	Ta_5	LR
P_1	0.265	0.274	0.157	0.068	0.060	0.044	0.044	0.573
P_2	0.298	0.338	0.153	0.080	0.060	0.048	0.040	0.452
P_3	0.322	0.322	0.189	0.092	0.068	0.052	0.048	0.587

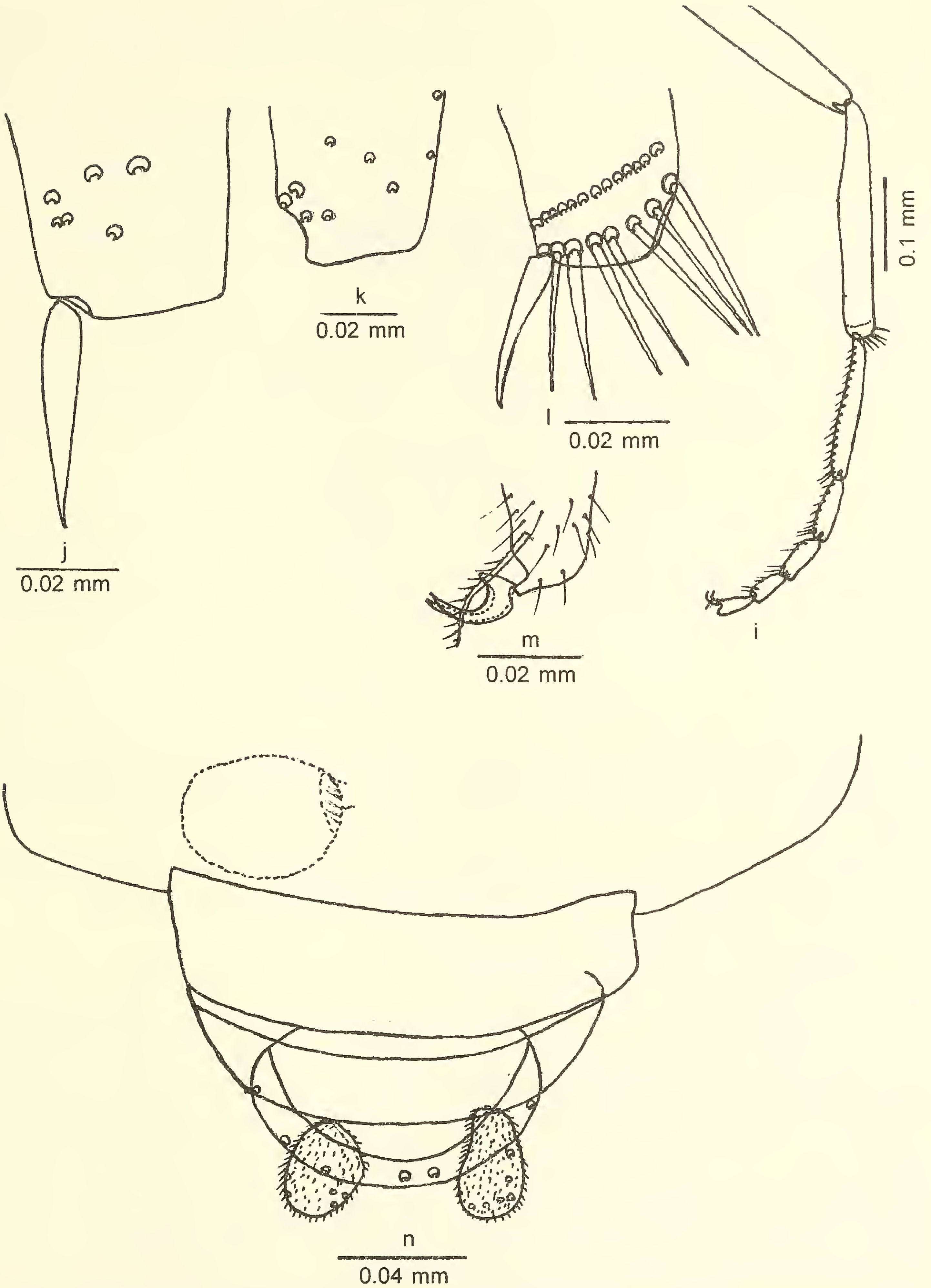
k
0.02 mm
l
0.02 mm
0.1 mm
j
0.02 mm
m
0.02 mm
i
n
0.04 mm

Fig. 2: i. hind leg, j,k,l. fore, mid and hind tibial apex respectively, m. apex of ultimate tarsomere, n. dorsal view of female genitalia

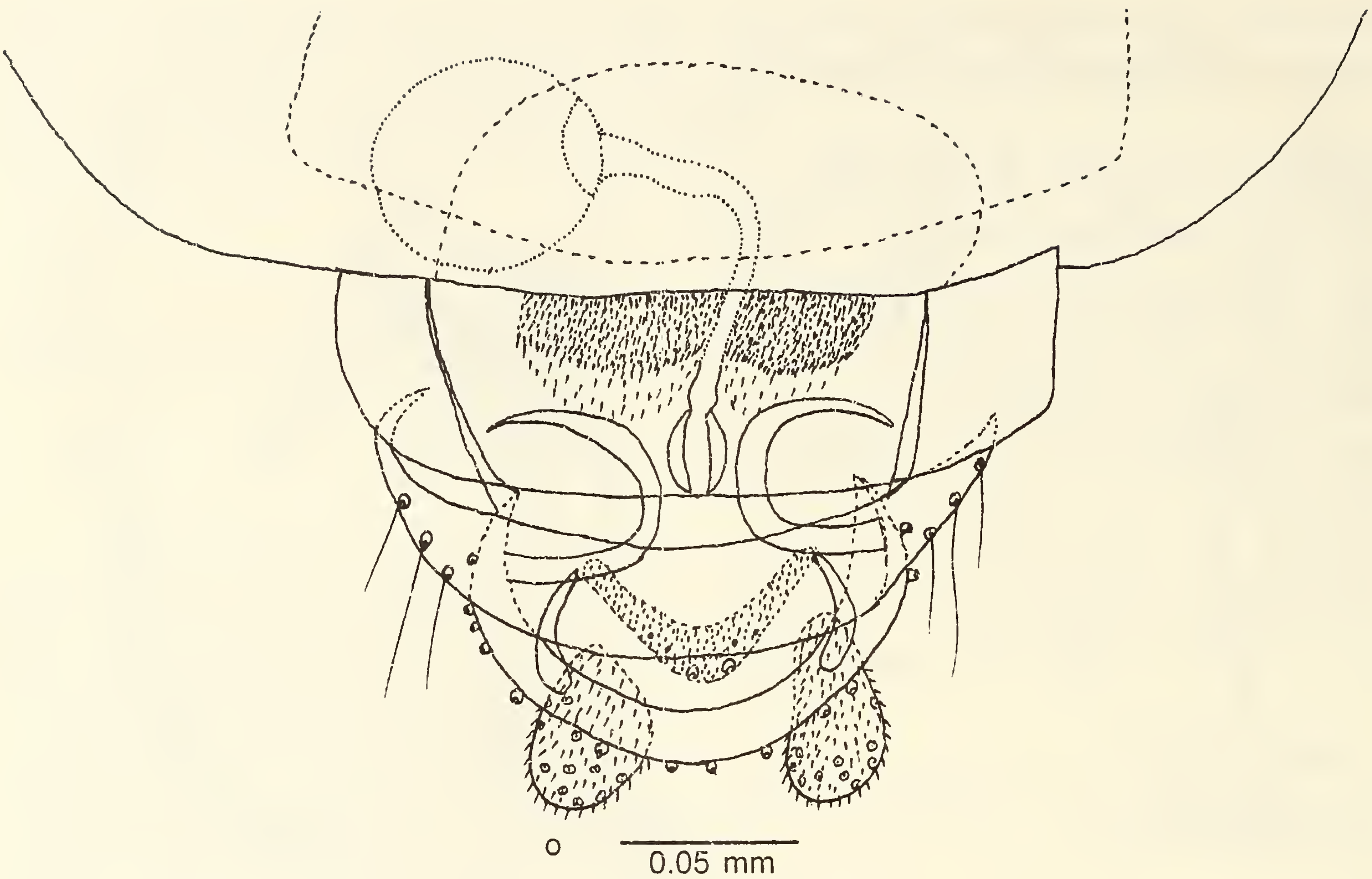

Fig. 3: o. ventral view of female genitalia

highly sclerotized. Gonapophysis VIII divided into dorsal and ventral lobes. Postgenital plate triangular with a pair of strong setae. Cerci club-shaped.

Holotype: ♀ on slide, INDIA: Uttar Pradesh, Agra, St. John's College Campus, 17.viii.1997, Coll. H.R. Sou, Det. Maheshwari, G.

Paratype: ♀ on slide, INDIA: Rajasthan, Camel Farm (Bikaner), 15.x.1997, Coll. H.R. Sou, Det. Maheshwari, G.

Systematics: *F. manasi* sp. nov. is, perhaps, the only known species of *Forcipomyia* which feeds on human blood. According to taxonomic characters, it comes closest to *F. jhapogi* Maheshwari *et al.* Since the species is haematophagous, the abdomen of the female is generally inflated by the accumulation of blood. *F. manasi* can be distinguished by the presence of a single spermatheca, highly sclerotized coxasternapodeme, large sensory pit on third maxillary palp and U-shaped clypeus. *F. jhapogi* can be separated from *manasi* by the presence of spermathecal neck and antepronotum with eight setae.

Etymology: Since the species feeds on human blood, it is named *manasi*.

DISCUSSION

Only a few species of biting midges are known intermediate hosts feeding on human blood. These are *Culicoides grahamii*, *C. inornatipennis* and *C. austeni*. *Forcipomyia* spp. feed on a variety of hosts such as insects, amphibia, birds and mammals. Those feeding on invertebrates have lacinia with retrorse teeth and coarsely toothed mandibles. *Forcipomyia manasi* sp. nov. is characterised by the margin of the apical portion of the labrum having a continuous row of teeth and the absence of sensilla coeloconica on first flagellomere of the antenna, which indicates its adaptation to feeding on human beings.

The fusion of the ramus with coxasternapodeme IX, the fusion of gonocoxite with tergite IX and absence of gonostylus in the female genitalia is a clear synapomorphy compared with other such as *F. confluens* and *F. conigera*. Presence of a single spermatheca in *F. manasi* and *jhapogi* is an apomorphic character, which isolates them from other spp. of *Forcipomyia*. *F. manasi* also resembles *F. barbipesi* but by the presence of a spermathecal diverticulum, an apomorphic character, *barbipesi* can be isolated from manasi. The mass culture of the species is being established in the laboratory for further studies on vectorial capacity.

ACKNOWLEDGEMENTS

I thank the Department of Science and Technology (DST), Govt. of India, New Delhi for financial support. I am also thankful to Dr. S.S. Shukla, Department of Forensic Sciences, Institute of Forensic Sciences, Agra for his valuable suggestion to determine host-specificity by the Precipitin method.

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A NEW SPECIES OF *EUGENIA* L., MYRTACEAE, FROM SEITHUR HILLS, TAMIL NADU, INDIA[1]

(*With one text-figure*)

R. Gopalan and S.R. Srinivasan[2]

Key words: *Eugenia seithurensis* sp. nov., southern Western Ghats, Tamil Nadu

A new species of *Eugenia*, from southern Western Ghats Tamil Nadu, India, is described and illustrated.

Introduction

Seithur hills in Virudhunagar district (formerly Kamarajar district), Tamil Nadu in southern Western Ghats is one of the richest areas in biodiversity. Botanical explorations in this hilly terrain were conducted in early 1970s by one of us (SRS). During these surveys a member of the Family Myrtaceae was collected in a shola forest, which was misidentified as *Eugenia discifera* Gamble and deposited at MH. When *E. discifera* was later collected by one of us (RG) in the Agasthiyamalai (Pothigai) hills, Tirunelveli district, it did not match with the earlier determined *E. discifera* referred to above. On critical study of the specimen, it was found that it was not *E. discifera* and that it was an undescribed species, which is described and illustrated herewith.

***Eugenia seithurensis* Gopalan & S.R. Sriniv. sp. nov.**

E. calcadensis Bedd. affinis, sed foliis obovatis, ad apicem abrupte acuminatis (acumine *c.* 3 mm longo); floribus axillaribus (solitariis vel binatis) vel terminaliter umbellatis; pedicellis 4-8 mm longis; stylo glabro; fructibus globosis differt.

Allied to *E. calcadensis* Bedd. but differs in leaves being obovate, abruptly acuminate (acumen *c.* 3 mm long) at apex; flowers axillary (solitary or in pairs) or in terminal umbels; pedicels 4-8 mm long, style glabrous; fruits globose.

Tree, up to 10 m tall; branches and branchlets terete, glabrous, lenticellate. Leaves opposite, simple; petioles 3-7 mm long, glabrous, rounded beneath, canaliculate above; lamina obovate, 3.2-5.4 x 2.9-3.5 cm, coriaceous, glabrous, punctate on both surfaces, attenuate at base, entire and recurved along margins, abruptly acuminate (acumen *c.* 3 mm long) at apex. Flowers axillary (solitary or in pairs) or in terminal 4-8-flowered umbels or cymes, bisexual, actinomorphic; pedicels stout, 4-8 mm long, hirsute; bract 1, linear-lanceolate or lanceolate-elliptic, *c.* 5 mm long, hirsute; bracteoles 2, linear-lanceolate, *c.* 3 mm long, hirsute. Calyx tube campanulate, 2-3 mm long, appressedly brown silky hairy; lobes 4 (2 + 2), subequal; outer sepals smaller, broadly ovate, 2.5-3.5 x 3-4 mm, thick, sparsely hairy, ciliate along margins, concave; the inner orbicular to suborbicular, 3-5 x 4-5 mm, punctate, sparsely hairy, broad at base, ciliate along margins, truncate or rounded at apex. Petals 4, obovate or elliptic-oblong, *c.* 11 x 7 mm, thick in middle, membranous along periphery, punctate, ciliate along margins above 1/3, obtuse at apex. Stamens many; filaments 4-10 mm long, glabrous; anthers globose, 2-loculed, basifixed. Ovary inferior, obconic,

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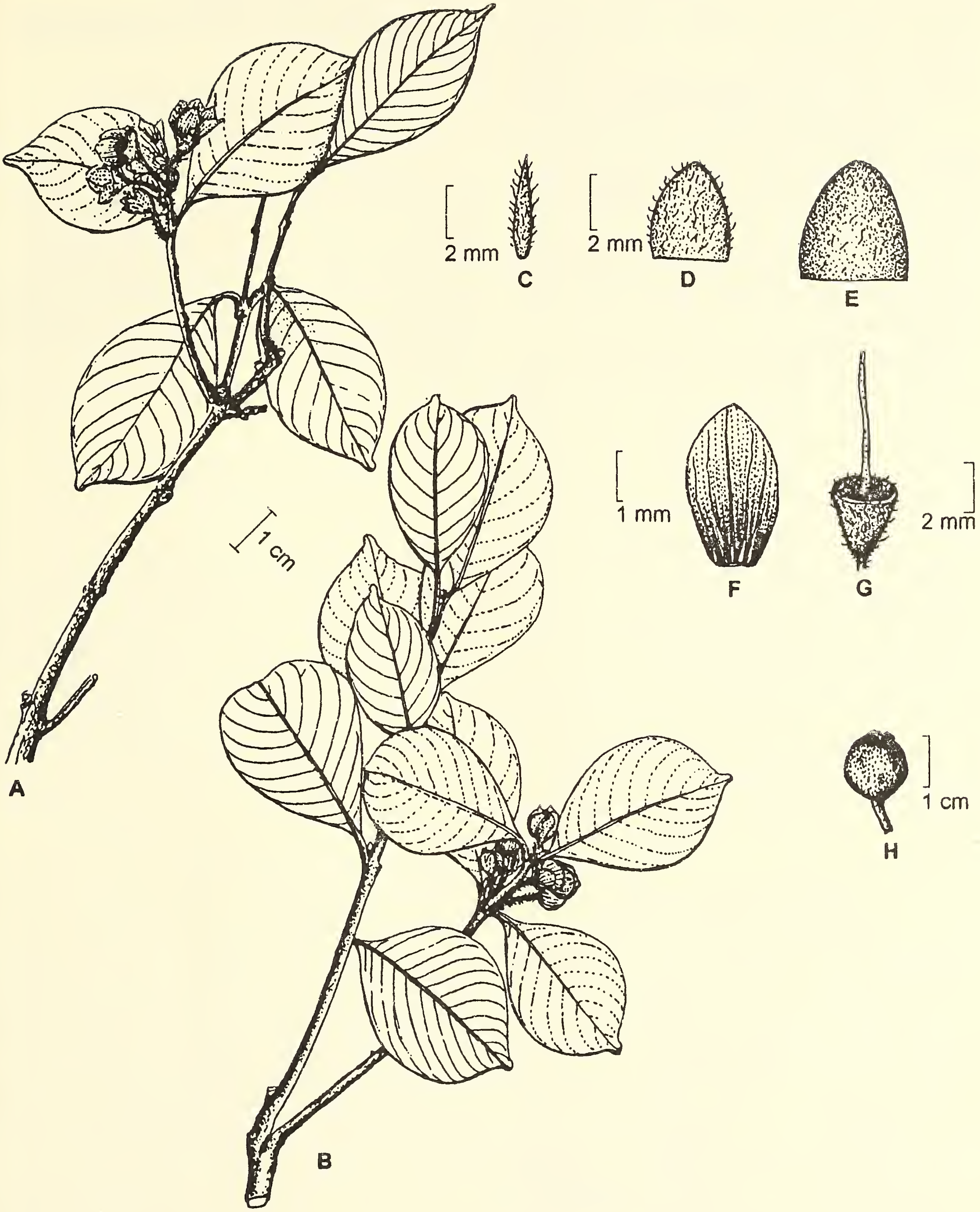
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G
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H

Fig. 1: *Eugenia seithurensis* sp. nov., A-B. Twigs with terminal inflorescence & axillary flowers, C. Bracteole, D. Outer sepal, E. Inner sepal, F. Petal, G. Pistil, H. Fruit

appressedly hairy, 2-3 (-4) mm long; style 5-7 mm long, thick, glabrous; stigma simple. Disc hairy. Fruits globose, *c.* 2 cm, crowned with persistent calyx lobes; seeds globose, *c.* 1.4 cm.

Holotype (S.R. Srinivasan 63532, CAL), isotypes (S.R. Srinivasan 63532, MH — acc. no. 120279 - 120283) and paratype (S.R. Srinivasan 65986, MH — acc. no. 120285 - 120292) were collected in between Deviar Estate and forest border of Kerala, Seithur Hills, Virudhunagar district, Tamil Nadu, at about 1,350 m above msl on June 12, 1979.

Rather rare in sholas, only a few trees were seen.

Fl. & Fr.: April-October.

Etymology: This species is named after the type locality.

ACKNOWLEDGEMENTS

We thank Dr. P. Daniel, Deputy Director, BSI, Coimbatore for encouragement and facilities, Dr. V.J. Nair, Scientist Emeritus, for the Latin diagnosis, Shri. N.C. Rathakrishnan, former Scientist, BSI, Coimbatore, for confirming the novelty and Dr. A.N. Henry, Scientist Emeritus, for suggestionss.

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SONERILA LONGIPETIOLATA MANICKAM *ET AL.*, A NEW SPECIES OF MELASTOMACEAE FROM TAMIL NADU, INDIA[1]

(*With one text-figure*)

M.M. JOSEPHINE, V.S. MANICKAM, C. MURUGAN, V. SUNDARESAN AND G.J. JOTHI[2]

Key words: *Sonerila longipetiolata* sp. nov., Kanyakumari district, Tamil Nadu

Sonerila longipetiolata Manickam *et al.*, a new species is described below with illustrations.

During recent floristic studies conducted along the southern Western Ghats, we collected specimens of an interesting species of *Sonerila* Roxb. On critical study, it was found to be a new species. Hence, it is described and illustrated here.

Sonerila longipetiolata sp. nov.
(Fig. 1)

Sonerila longipetiolata sp. nov. est affinis ad *S. travancorica* Bedd. sed est dissimilis folia base inaequali, petiolata longa, corolla emarginata, indumenta molle et floris numerosis.

Typus: INDIA: Tamil Nadu, Kanyakumari district, Muthukuzhivayal path *c.* 1,300 m, 22.xii.1999, Coll. V. Sundaresan and M.M. Josephine 20104 (Holo. XCH, Xavier's College, Palayamkottai).

Perennial herb, *c.* 30 cm high. Stem 3-5 mm in diam; adpressedly villous, branched, base terete, apex two channelled; internodes 2.5-11.0 cm long. Leaves opposite, unequal; petiole 1.0-7.0 cm long, villous; blade ovate-elliptic, 1.0-7.0 x 1.5-5.0 cm, coriaceous, softly adpressedly villous, base unequal, slightly cordate, margins sub entire, ciliate, apex acute, veins 2-3 pairs, pinkish beneath. Inflorescence scorpioid cyme, terminal. Peduncle 3.0-5.0 cm long, puberulous. Pedicel 1.0-1.5 cm long, puberulous. Flowers 10-15 per peduncle, mauve-deep pink. Calyx 0.7-1.0 cm long, tube infundibuliform, teeth 3, short, glandular hairy. Petals 3, free, 1.0-1.2 x 0.7-0.75 cm, glabrous within, glandular hairy without mid nerve, apex emarginate, obovate-elliptic, 8-9 nerves, prominent. Stamens 3, equal, *c.* 1.0 cm long, free; anther *c.* 0.7 mm long, yellow, oblong, divaricated, much attenuated upwards; filament *c.* 6.2 mm long. Ovary inferior, 1.0 x 0.33 cm, glandular hairy; ovules numerous. Style simple, filiform, 1.0-1.2 cm long; stigma small, capitellate. Capsule trigonous, 0.75-1.0 x 0.31-0.33 cm, six ribbed, glandular hairy. Seeds numerous, *c.* 1.0 mm long, raphe excurrent on the side near the top.

Fl. and Fr.: December-January.

Habitat: Understorey of evergreen forest, semi-shaded, associated with *Bambusa arundinacea* Willd.

Table 1: Comparison between *S. travancorica* and *S. longipetiolata*

Character	*S. travancorica* Bedd.	*S. longipetiolata* sp. nov.
1. Leaves	elliptic-lanceolate; 1.0-3.0 x 1.5-2.0 cm; base equal, narrow	ovate-elliptic; 1.0-8.0 x 1.5-5.0 cm; base unequal, cordate
2. Petiole	Short, 2.0-3.0 cm	Long, 6.0-7.0 cm
3. Indumentum	Rough	Soft
4. Inflorescence	±5 flowered	±15 flowered
5. Calyx	apex acuminate	apex obtusely acute
6. Corolla	apex mucronate	apex emarginate

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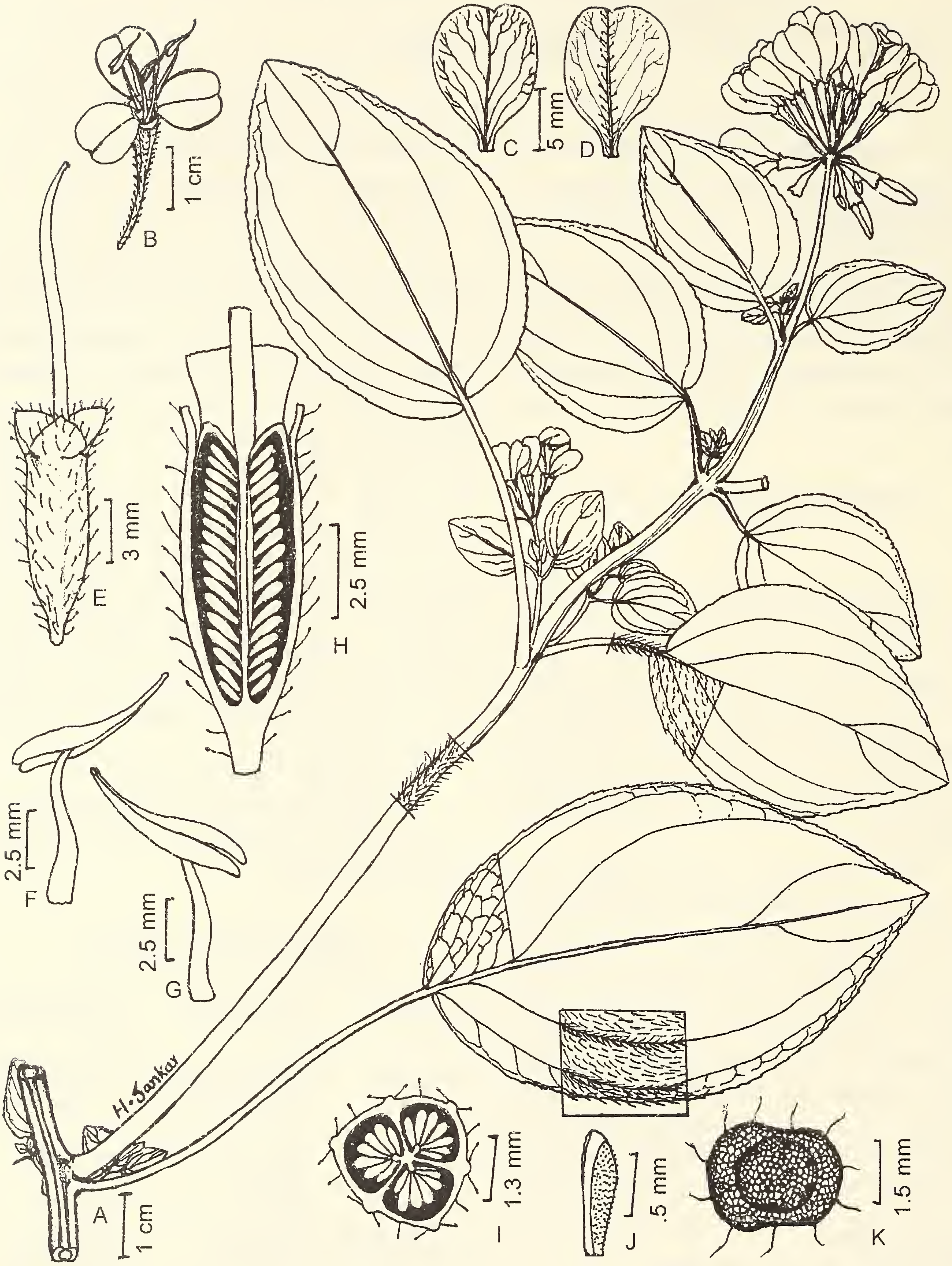
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Fig. 1: *Sonerila longipetiolata* sp. nov., A. Habit, B. Flower, C & D. Petal (Dorsal & Ventral view), E. Pistil with Calyx, F. & G. Stamens, H. ovary (l.s.), I. Ovary (c.s.), J. Seed, K. Stem (c.s.)

Sonerila longipetiolata is allied to *S. travancorica* but differs from it as shown in Table 1.

Status: As the species is restricted to only one locality, it must be categorized as rare; since the number of individuals is small, vulnerable is probably more correct.

Etymology: The species is named after its characteristic long petiole.

ACKNOWLEDGEMENTS

We thank Dr. R. Gopalan, Botanical Survey of India (S. Circle), Coimbatore for his critical comments on the taxon. Our gratitude to Chief Wildlife Warden, Field Director, KMTR for permission to carry out the survey. We also thank the University Grants Commission (UGC) for financial assistance.

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A NEW SPECIES OF SPIDER OF THE GENUS *TIBELLUS* SIMON (ARANEAE: THOMISIDAE) FROM JHENIDAH, BANGLADESH[1]

(*With six text-figures*)

V. Biswas[2] and D. Raychaudhuri[3]

Key words: New species, spider, *Tibellus*, Araneae, Thomisidae, Bangladesh

A new species of spider genus *Tibellus* Simon, *T. shikerpurensis* is described and illustrated from Jhenidah, Bangladesh.

Introduction

Spiders of the genus *Tibellus* Simon (Family: Thomisidae) are poorly known in Bangladesh although a few records, on different species, were found (Chowdhury and Nagari 1981, Biswas *et. al.* 1993, Okuma *et. al.* 1993, Begum and Biswas 1997). Several species on the other hand, of the genus are known from countries like India (Tikader 1980, Tikader and Biswas 1981) and Pakistan (Dyal 1935).

The genus *Tibellus* Simon is being reported for the first time from Bangladesh and the same is being described as *T. shikerpurensis* sp. nov. The types are at present in the collection of the Department of Zoology, Government P.C. College, Bagerhat, Bangladesh.

Materials and Methods

Collection and preservation of the spider specimens were made following Kaston (1972) and Tikader (1987). The materials were studied with a Stereozoom Binocular Microscope, model Zeiss, SV8. All the measurements are taken with an eyepiece.

The species was identified by following Tikader (1980, 1987) and was confirmed by the Zoological Survey of India, Kolkata.

Tibellus shikerpurensis sp. nov.

(Figs 1-6)

General: ♀, Brownish-green; cephalothorax brownish-green; legs greenish; abdomen greenish-white.

Measurements (in mm): Total length 6.40; carapace 2.20 long, 2.00 wide; abdomen 4.20 long, 3.10 wide.

Cephalothorax: Broad, slightly longer than wide, wider near base, clothed with fine hairs and pubescence (Fig. 1); cephalic region raised and produced anteriorly, with straight anterior margin. Eyes in 2 rows, both the rows strongly procurved, ocular area wider than long; postero-laterals distally placed and larger than others; 2 longitudinal brownish bands running between the base of posterior eyes and posterior margin clothed with spines and hairs. Chelicerae strong and stout, clothed with sharp spines, each of inner and outer margins with 2 teeth (Fig. 2). Palps long, filiform, 1.2 mm in length (Table 1) each covered with sharp spines and setae. Maxillae longer than wide, medially wide and anteriorly scopulate (Fig. 3). Labium wider medially, anteriorly narrowing and scopulate (Fig. 3). Sternum heart-shaped, pointed, posteriorly clothed with spines (Fig. 4). Legs long and slender, with spines and hairs; leg formula 1243 and the measurements (in mm) as in Table 1.

Abdomen: Longer than wide, posteriorly narrowing, blunt, clothed with hairs and pubescence; dorsum decorated with brownish

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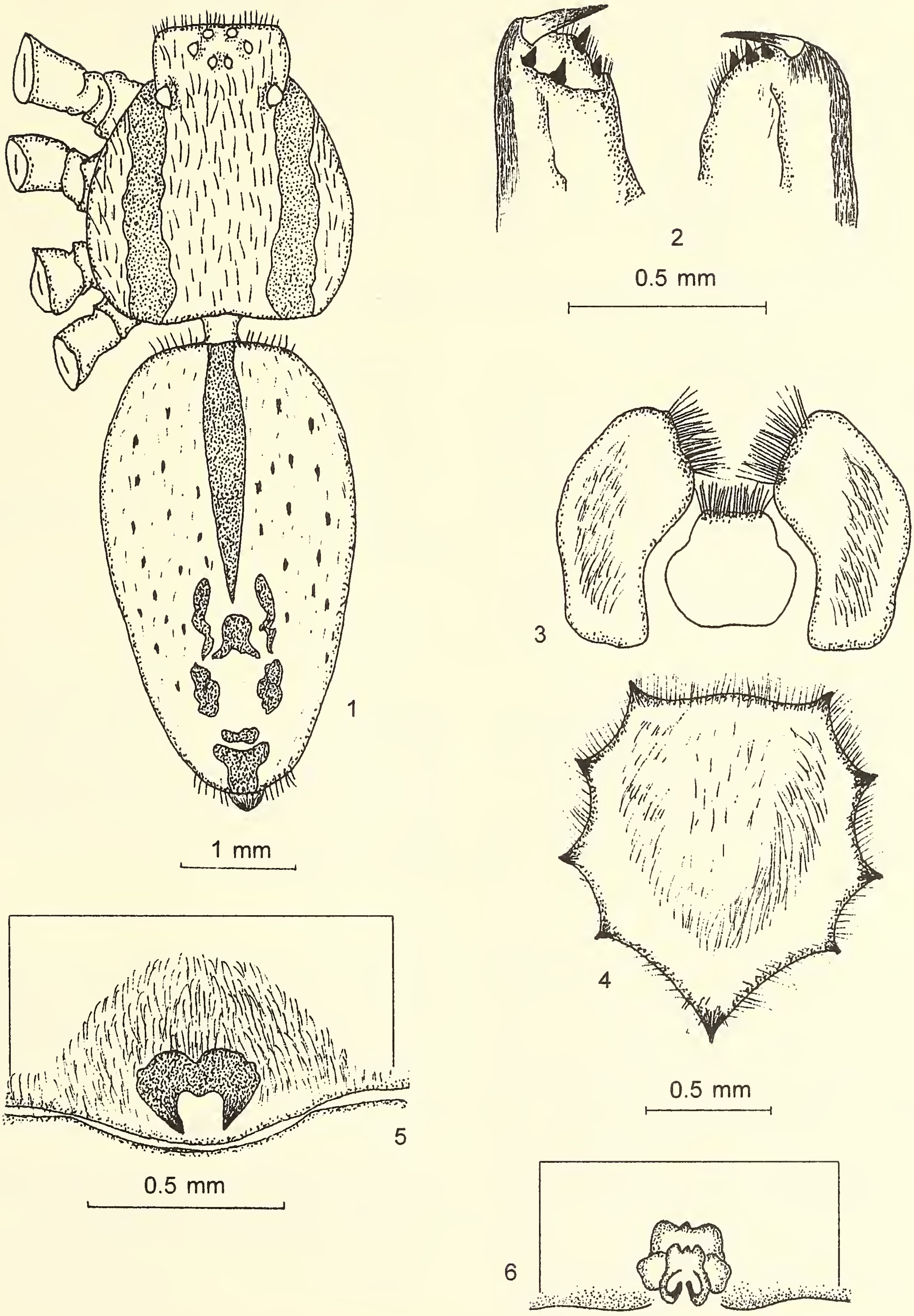

Figs 1-6: *Tibellus shikerpurensis* sp. nov., Female Holotype, 1. Female dorsal view (legs omitted), 2. Chelicera, 3. Maxillae and Labium, 4. Sternum, 5. Epigynum, 6. Internal genitalia

Table 1: Measurements of legs and palps for (♀) *Tibellus shikerpurensis* sp. nov.

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
I	3.8/3.8	1.0/1.0	2.5/2.5	2.0/2.0	1.3/1.3	10.6/10.6
II	3.5/3.5	0.9/0.9	2.3/2.3	2.0/2.0	1.0/1.0	9.7/9.7
III	3.0/3.0	0.5/0.5	2.0/2.0	1.9/1.9	0.9/0.9	8.3/8.3
IV	3.4/3.4	0.5/0.5	2.0/2.0	1.9/1.9	0.9/0.9	8.7/8.7
Palps	0.3/0.3	0.2/0.2	0.3/0.3	—	0.4/0.4	1.2/1.2

markings and patches; epigyne and internal genitalia as in Figs 5 and 6.

Material examined: Type-Data: Holotype: ♀ in spirit will be deposited in the Department of Zoology, University of Dhaka, Bangladesh.

Type locality: Shikerpur, Jhenidah, 18.vii.1993, Coll. V. Biswas.

Paratype: 1♀, same as for the holotype.

Distribution: BANGLADESH: District Jhenidah.

Etymology: The species has been named after the type locality.

Remarks: The species *T. shikerpurensis* sp. nov. resembles *T. chaturshingi* Tikader (Tikader 1980) but stands distinct because of the following

1. Cephalic region raised and produced.
2. Anterior row of eyes and posteromedians forming a hexagon.
3. Cephalothoracic bands nearly straight.
4. Abdomen not overhanging cephalothorax with several black markings.
5. Much different epigynum.

These differences justify the recognition of the species as new to science.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. S.C. Majumder, Scientist-SD, Sunderban Field Research Station, Zoological Survey of India, Canning, West Bengal, for confirming the identity of the species and the Head, Department of Zoology, University of Calcutta, for providing laboratory facilities.

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FURTHER CONTRIBUTION TO BIOSYSTEMATICS OF *CHENOPODIUM*, REPORTING THREE NEW SPECIES FROM NORTH INDIAN PLAINS[1]

(*With three text-figures*)

S.C. Pandeya[2,3] and Amita Pandeya[2]

Key words: *Chenopodium adpressifolium* sp. nov., *C. sagittatum* sp. nov., *C. hastatifolium* sp. nov., photonastic movements

Three new species of *Chenopodium* aggregate occurring in the north Indian plains have been distinguished and described as *Chenopodium adpressifolium* sp. nov., *C. sagittatum* sp. nov. and *C. hastatifolium* sp. nov.

Introduction

Three new species of *Chenopodium* aggregate occurring in the north Indian plains have been distinguished and described as *Chenopodium adpressifolium* sp. nov., *C. sagittatum* sp. nov. and *C. hastatifolium* sp. nov. Earlier Pandeya *et al.* (1998) have communicated two new species of the genus from the north Indian plains.

Further, in both extensive and intensive surveys over the last several years, three new species of the genus *Chenopodium* have been distinguished from the north Indian Plains (alt. 100-250 m). All the three species are edible and occur naturally as weed in winter crop fields, in gardens and other moist places. They start growing in November and flower from January to April. Ecoclimate of the region is Tropical semi-arid and soils are Pleistocene with fresh alluvium of great depths. The specimens are deposited in Raja Balwant Singh College, Agra, India.

The three suspected species were put through a Provenance Trial (neutral garden experiment) at Agra for three consecutive years for observing any plasticity therein. In neutral garden experiments, the plants collected from various habitats are grown together side by side under similar soil and climatic conditions in order to eliminate features developed due to differences of habitat. The quantified description of the three new species pertains to the neutral garden experiments.

Chenopodium adpressifolium Pandeya & Pandeya sp. nov.

Affinis *C. album* Linn. Sp. Pl. 219, 1753.

Differt a *C. album* Linn. f. habitus, positus foliis, folia crasso, marginemque laminae, folia photonasticus, nervo rosea.

Herbae annuae, erectae. Herba 1 m alta. Caule fibro, erecto, angusto costato, ramoso. Ramosae longior ad 10-25 cm, longis basales rosettus. Folia ovatus, dentatus, marginemque, laminae 3-5 cm to 1.5-3.0 cm, pubescentia in primordiis, nervo rosea. Petiola 2.5-3.5 cm, rosea. Inflorescentia spikus, pedunculata 18 cm longum, brevis spikus 1-2 m ad folia axillaris. Flores perianthus 5, rosea. Stamina 5, longior quam perianth. Stigma pilosum, bifidis, brevis-brunnea. Semina brunnea 1.26-1.30 x 0.61-0.67 mm.

Holotypus 910 et positus Raja Balwant Singh College Agra, India. lectus Agra ad February 26, 1999. Isotypus *Ibid.* S.C. Pandeya & A. Pandeya. Fig. 1.

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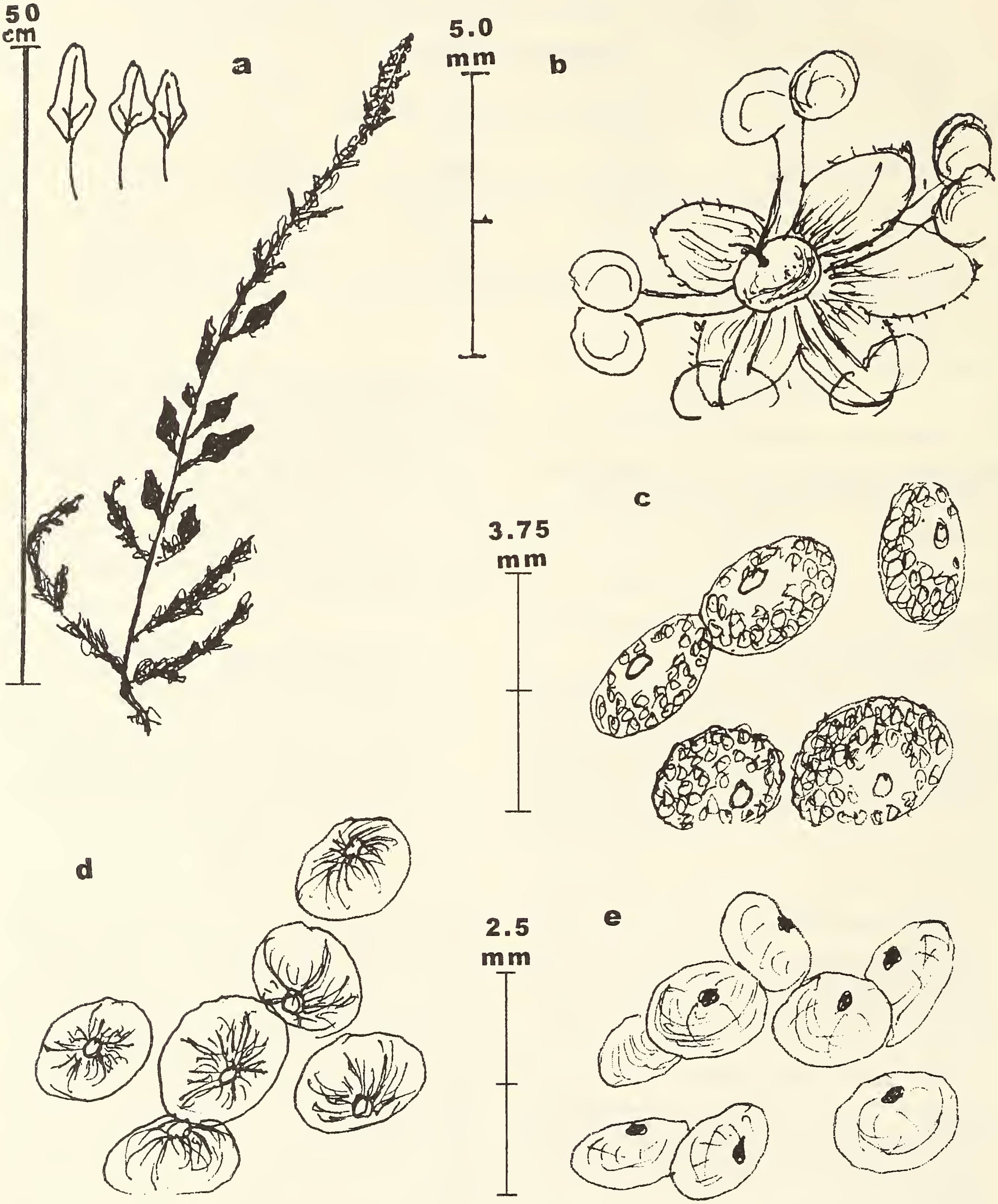

Fig. 1: *Chenopodium adpressifolium*, a. Habit and maximum size of leaves, leaves turn crimson during senescence, b. Filaments longer than perianth, c. Purple perianth upon maturity, d. seeds with pericarp, e. seeds without pericarp

An erect annual herbaceous plant. Starts growing in January, flowers in February/March and senesces by April/May; Height up to 1 m; Stem fibrous and hard, somewhat ridged, greenish-red to purple striped, turning homogeneously crimson upon maturity; Branches limited up to 10 cm from the base, decumbent, longest branch 20-25 cm; giving mature plant a rosette at the base with internodes 2-3 cm; Leaves ovate, petiole and lamina in one line, erect, attached to the node at an angle of 70-75° during day and completely adpressed at night (photonastic movement), petiole 2.5-3.5 cm, reddish-green; lamina olive green, veins reddish-green, dentate margin purple in mature leaves, dentations sharp and pointing upwards, lamina 3.0-5.0 x 1.5-3.0 cm, 0.56-0.8 mm thick and brittle, heavy mealiness on primordia, young stem leaves and perianth, lamina and petiole turn crimson upon maturity, terminal spike up to 18 cm long, few small spikes (1-2 cm) in axil of upper leaves; Flowers- perianth 5, central vein prominent; Stamens 5, longer than perianth, anthers coming out of flowers, feathery stigma bifid, small, purple, seeds covered with pericarp with a circular opening on the top, biconvex, disc-shaped, dark brown, 1.26-1.3 x 0.61-0.67 mm. Holotype deposited at Raja Balwant Singh College, Agra, India. No. 910. Fig. 1.

Etymology: The species has been named so as its leaves get completely adpressed to the stem during night owing to photonastic movement.

The specimen was sent to Prof. Pertii Uotila of Finland. He (1997, pers. comm.) opined that *C. adpressifolium* belongs to the group of *C. album* resembling in seed shape, size, and surface structure, as well as in the general shape of the leaves. The two species under discussion differ largely in their habit, position of the leaves, leaf size, leaf thickness and photonastic movement of leaves in the former species. He was of the view that the taxonomy of *C. album* in India needs revision.

Chenopodium sagittatum Pandeya & Pandeya sp. nov.

Affinis *C. moquianum* Aellen.

C. moquianum Aellen affinis, ab ea differt: habitus, ramosa longior, folia gigantea, supra, lobi, lamina sagittus.

Herbae, annuae, erectae, 3.65 m alta. Caule erecto, roseo, basales circumference *c.* 12 cm. Ramosa longior ad 65 cm. Folia petiolata *c.* 10-12.5 cm longa, diam 21.5 cm, lamina sagittus 17-20 cm x 10-12 cm, lobus 2-2.5 cm. Inflorescentia terminalis, spikus, bracts lanceolatus, rosea, pubescentibus. Stamina 5, equilongus perianthus. Stigma bifidus, longa *c.* 0.64 mm, erectae, ovary diam 0.32 mm. Semina nigra brunnea, diam 0.91- 0.96 mm.

Holotypus 911 et positus Raja Balwant Singh College, Agra, India. lectus Agra ad March 12, 1999. Isotypus *Ibid.* S.C. Pandeya & Amita Pandeya. Fig. 2.

An erect annual herbaceous plant growing to 3.65 m height, starts growing in January-February, flowers from mid-April and spikes fully mature by May end; Stem ridged, red-striped, turning completely red up to apex upon maturity, circumference at the base up to 12 cm branching throughout, branches straight, stiff and at an angle of 30-40° from the node, branches parallel to each other in acropetal order, number of branches on mature plants 40-50. Several branchlets on each branch, longest branch up to 65 cm, when young red blotch on nodes; Leaves-petiole at an angle of 35-40° to stem and lamina 30° to petiole, at night both petiole and lamina become straight adpressed to the stem at an angle of 80-85°, lamina boat-shaped at night clasping the stem, exhibiting the photonastic movement. Petiole and lamina venation light purple, petiole 10-12.5 cm long, diameter 2.15 cm lamina arrow shaped (sagitate) with small side lobes pointing upwards, lamina 17-20 cm long and 10-12 cm at the broadest part, side lobes 2-2.5 cm, sometimes bifid, young lamina greyish-green,

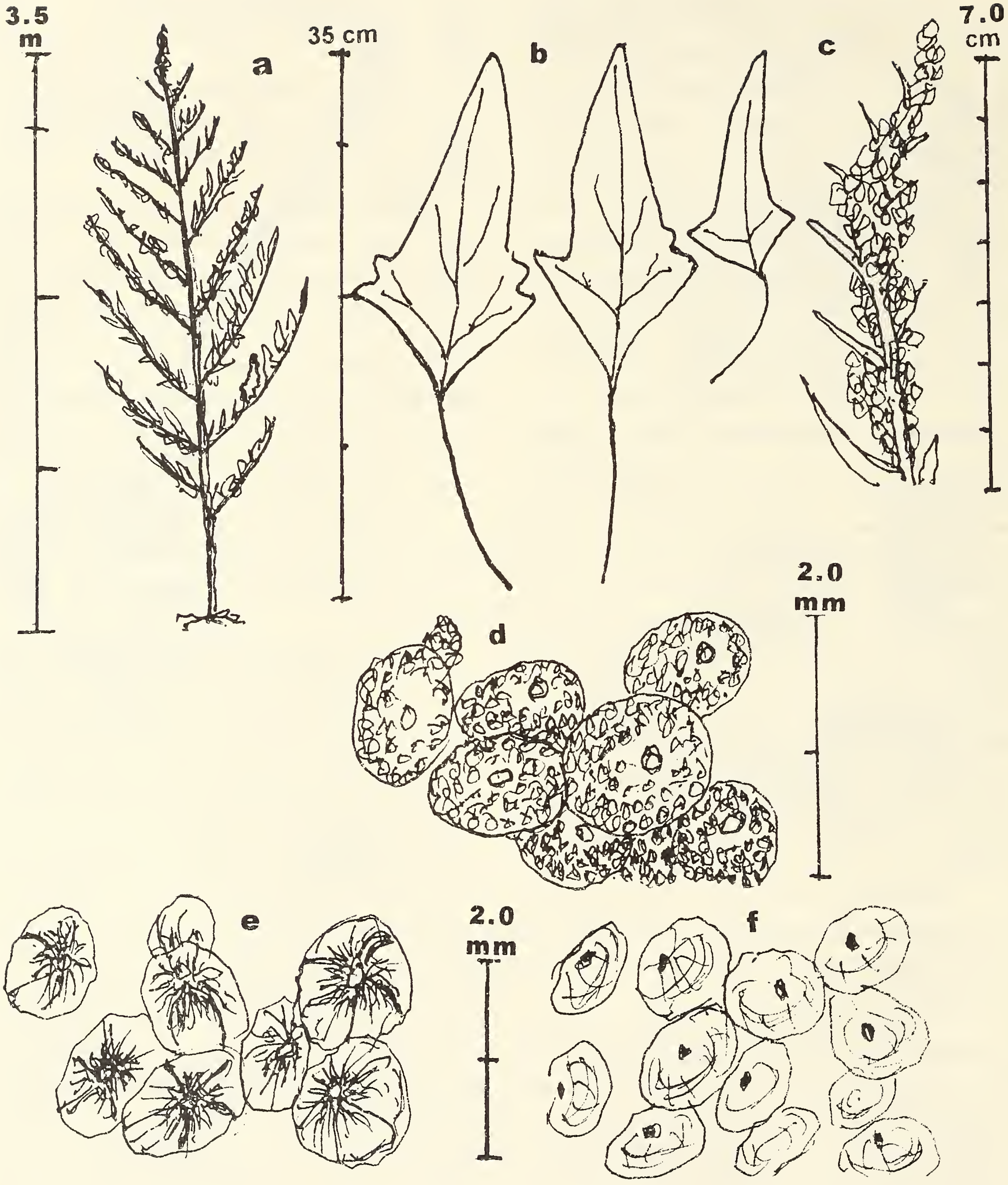

Fig. 2: *Chenopodium sagittatum*, a. Habit with acropetal branching, b. Maximum size of leaves, old leaves turn crimson, c. Flowering branch, anthers coming out of the flowers, d. Crimson perianth upon maturity, e. Seeds with pericarp, f. Seeds without pericarp

heavy mealiness. Both petiole and lamina turn crimson during senescence. Lamina 0.34 mm thick in vertical section, stele with both upper and lower epidermis red in colour. Inflorescence terminal along with branchlets up to 15 cm long, branches and branchlets bear up to 12 cm long spikes, spikes and lanceolate bracts all turn crimson upon maturity of seeds. Flowers 1.1 mm across, perianth 5, connate at base, greyish-green when young, crimson upon maturity, heavy mealiness. Stamens 5, anthers dehisce soon after opening of flowers, filaments equal to perianth. Stigma bifid, purple and erect, 0.64 mm long above ovary, diameter 0.32 mm. Seeds disc-shaped, notched, blackish-brown, diameter 0.91-0.96 mm, width 0.6-0.61 mm. Holotype deposited at Raja Balwant Singh College, Agra, India. No. 911. Fig. 2.

Etymology: The species has been named so as it has a characteristic sagittate lamina margin.

For this species Uotila (1997, pers. comm.) opined that it might be close to a taxon called *C. moquianum* Allen. *C. sagitattum* can easily be distinguished from the said group on account of its very large leaves. The leaves in *C. moquianum* are small and resemble Chenopod.

Chenopodium hastatifolium Pandeya & Pandeya sp. nov.

Affinis *C. ficifolium* Sm. Fl. Brit. 1: 276 (1800).

C. ficifolium Sm. Affinis ab ea differt folia tribus lobis obscuris, oblongo; foliis minuta, inferio.

Herbae annuae, erectae *c.* 1 m alta, ramosae 20-25, longior ramosae 60-70 cm. Caulis rosea green, stripus basales circumference *c.* 2.7 cm, folia 3-lobus, lobus oblongo, dentibus - 2, lamina pubescens, petiolata 3-4.5 cm longa. Inflorescentia terminalis, spikes 5-10 cm longis, Folia basales spikes parvi. Flores parvi, perianthus 5 basales connatis. Stamina 5 acquilongis perianthus, purplish. Carpella-stigma longo, bifidus. Semina biconvex, diameter 0.96-1.02 x 0.56-0.61 mm, brunnei.

Holotypus 912 et positus Raja Balwant Singh College, Agra, India. lectus Agra ad March 15, 1999. Isotypus *Ibid.* S.C. Pandeya & Amita Pandeya. Fig. 3.

An annual erect herb, up to 1 m, profusely branched (20-25 main branches), longest middle branches 60-70 cm, starts growing in November-December, flowers from February-March, fruits in March and senesces by April end. Stem greenish-red striped, ridged, circumference at base up to 2.7 cm. Leaves green, completely crimson upon senescence, 3- lobed, middle lobe oblong 3.5 x 0.6-1.2 cm, with two dentations, basal two lobes pointing upwards, 0.6-1.8 cm long, sometimes with 1-2 dentations, lamina 0.2-0.26 mm thick with heavy mealiness when young. Petiole 3-4.5 cm long. Inflorescence greyish-green, turning crimson upon maturity of seeds due to perianth changing to crimson, terminal spike 5-10 cm, several small spikes in axil of leaves; Flowers-perianth 5, connate at base, central vein prominent. Stamens 5, equal to perianth. Stigma purple bifid, long and moustache-like, each arm 0.3-0.4 mm long. Seeds biconvex covered with pericarp with a circular opening on the top. Seeds without pericarp 0.96-1.02 x 0.56-0.61 mm, dark brown with a small notch. Holotype deposited at Raja Balwant Singh College, Agra, India. No. 912. Fig. 3.

Etymology: The species has been named on the basis of its hastate leaf margin.

For this specimen Uotila (1997, pers. comm.) is of the view that it is close to *C. ficifolium* although the leaf shape is not very typical of that taxon. However, the interspecific taxonomy of the species is not completely known.

ACKNOWLEDGEMENTS

We thank Prof. Perti Uotila, Finish Museum of National History, University of

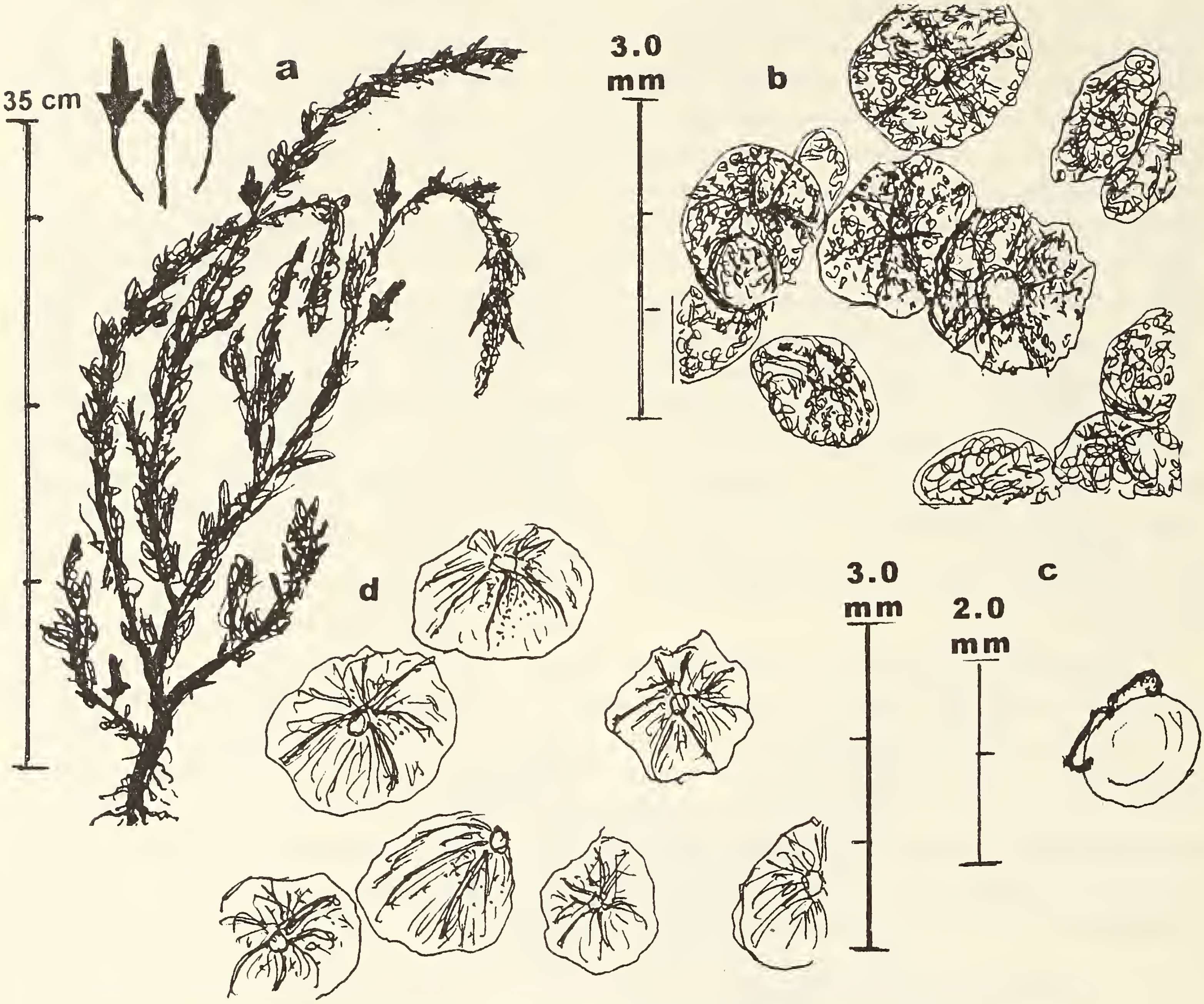

Fig. 3: *Chenopodium hastatifolium,* a. Habit with maximum size of leaves, crimson old leaves, b. Heavy mealiness on flowers, c. Bifid stigma with long arms, d. Perianth turns reddish upon maturity

Helsinki, Finland for critically examining the three specimens and giving his expert opinion. We thank Prof. A.B. Bhatt of HNB Garhwal University, Srinagar (UA) for critically going through the final manuscript, Dr. V.P. Bhatnagar, Head and Dr. Anil K. Bhatnagar both of Botany Department, Dayalbagh Educational Institute, Agra for their cooperation and facilities, Dr. R.K.S. Rathore, Head Department of Botany, RBS College Agra for discussions and Dr. R.S. Parekh for permission to work on his farm at Poiya Ghat, Agra.

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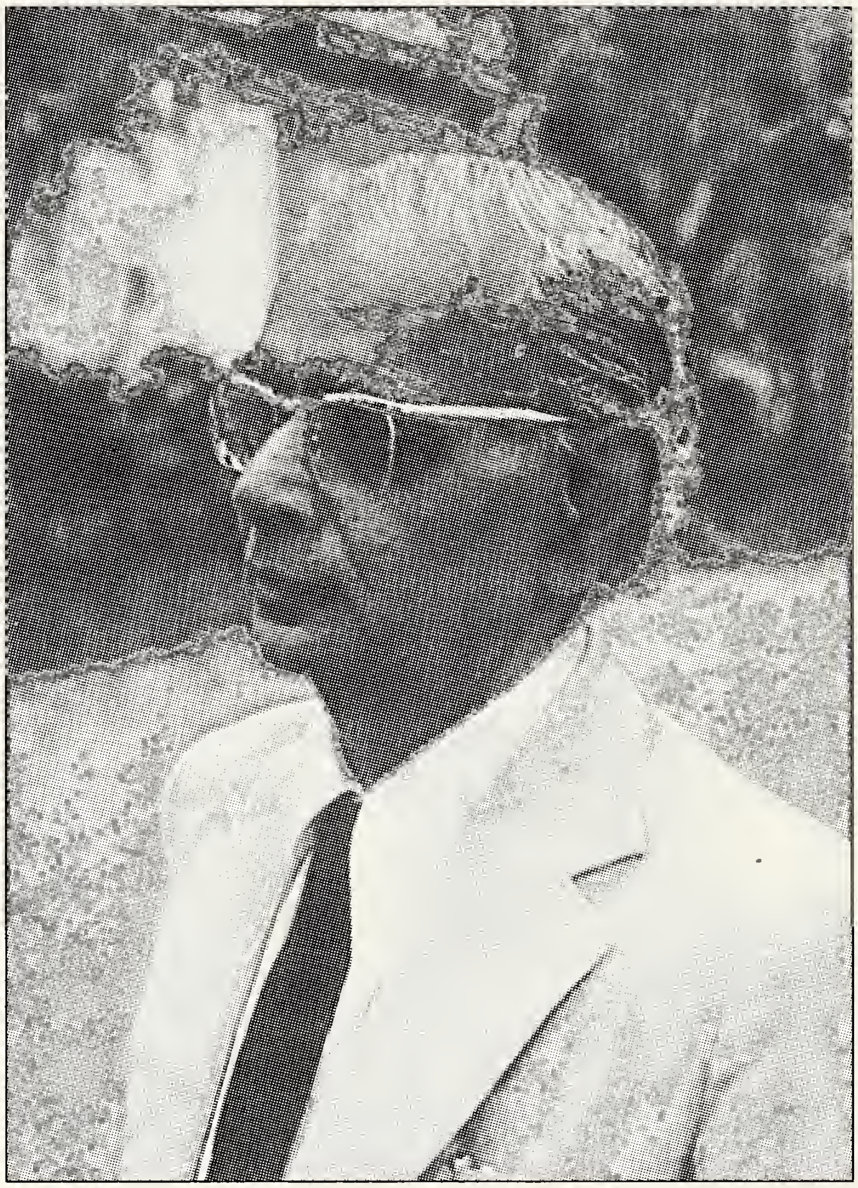

Professor M.S. Mani
(1908-2003)

OBITUARY

PROF. M.S. MANI

The year was 1968, as a young postgraduate student of Zoology at the Department of Zoology, St. John's College, Agra, I had the opportunity to meet Prof. Mani when he used to take classes while serving as Emeritus Professor. Thus, I had the golden opportunity to hear his lectures while I was in the final year M. Sc. class. I still remember the scholarly presentation and disposition of Prof. Mani.

Professor Mani was an affectionate and highly respected man, who led a very disciplined life. He worked hard, and it is not surprising that he wrote over 35 books and more than 300 papers. Even at the age of 94, he went to Presidency College and worked. Personally, he was always extremely kind towards me. In 1979, when I asked him for some Chalcididae specimens for my studies on loan, he sent me several boxes of specimens with an affectionate letter saying that I need not return them. He gladly wrote a foreword for my book on Parasitic Hymenoptera in 2001. I consider myself fortunate to have been associated with such a great man.

Prof. Mahadeva Subramania was born on March 2, 1908 at Thanjavur (Tanjore), Tamil Nadu. After schooling at K.S. High School, Thanjavur, he joined the Govt. College, Coimbatore for his Intermediate in 1928. He later joined the Madras Medical College, but had to leave due to financial constraints. In 1933, he proceeded to Calcutta (Kolkata) in search of a suitable job and later joined as a tutor-cum-demonstrator in Physics on a part-time basis at Bangabasi College, Sealdah. At the same time, he worked at the Indian Museum of the Zoological Survey of India, Calcutta as an honorary research student. A few years later, he got a small job at the ZSI, started working on plant galls and gall insects, and soon became interested in Chalcidoidea. In 1937, he obtained an M.A. degree from the University of Madras, on the basis of his research papers in Entomology. He was the only candidate to be so honoured. In 1937, M.S. Mani joined the Imperial Agricultural Research Institute (now the IARI, New Delhi) as a Research Assistant under Dr. H.S. Pruthi. In 1940, he published his work 'Biological Notes on the Chalcidoidea' with Dr. Pruthi. In 1944, Dr. Mani resigned his post at IARI because of some differences between him and Dr. Pruthi. For some time, he had no job, but worked as a German language Translator for the Indian Army at New Delhi (Dr. Mani knew several European and Indian languages). In 1945, Dr. Mani joined St. John's College, Agra as a lecturer, and there he prospered. He obtained his D.Sc. degree from the Agra University for his work on galls and gall insects of India in 1947. In 1950, he established the famous School of Entomology at St. John's College, Agra, where he initiated research on various aspects of entomology. It was here that he initiated pioneering research on High Altitude Entomology and led several entomological expeditions to the Himalaya during 1953-56. These records were published in the *JBNHS*. Prof. Mani joined the Zoological Survey of India as Deputy Director in 1956 on an invitation from the Central Ministry, New Delhi and later served the Institution as Officiating Director. In 1968, he returned to the School of Entomology, Agra, as Emeritus Professor and continued there until 1984, when he went to Chennai. He worked at the Zoological Survey of India, Chennai Regional Station as a Principal Investigator of a DST Project and later shifted to the Botany Department, Presidency College, Chennai. Since 1990, he was working there as Emeritus Professor.

Prof. Mani led an Indian delegation of Zoologists to the USSR in 1963. He represented India in the Man and Biosphere (MAB) Committee on Alpine and Arctic Ecology in Lillehammer, Norway in 1972. He was a Visiting Professor of Entomology at Tribhuvan University, Kathmandu, Nepal in 1975. Gordon Edwards of Colorado named him the Dean of High Altitude Entomology in 1971. He was awarded the Scientist of the Year award by Presidency College in 2000. Recently, the Ministry of Environment and Forests, Govt. of India awarded him the E.K. Janakiammal award for taxonomy, 2001, which carried a cash award of Rs. 1 Lakh.

With the demise of Prof. M.S. Mani, not only India but the world has lost a renowned scientist.

■ T.C. NARENDRAN

REVIEWS

1. BEAUTIFUL ORCHIDS OF NEPAL by Keshab R. Rajbhandari and Sushila Bhattarai. Published by authors. 2001. Pp. i-viii + 1-220 (22 x 14 cm). Price Rs. 1,200/-.

This book covers 101 orchid species belonging to 43 genera out of the 363 species belonging to 97 genera found in Nepal. Orchids attract professionals like botanists, horticulturists, florists as well as amateur plant lovers due to their showy flowers, fascinating structures and variety of colours. This handbook is useful for identifying some of the common showy orchids found in Nepal, and perhaps intended for the lay reader who generally does not want to read scientific terminology to identify plants. The book is mainly based on good and well-identified photographs, some of which are taken from potted cultivated plants. The book has limited value for amateurs, as it does not cover all the orchids from Nepal and it does not give identification keys, although the short descriptions given are sufficient to recognize the species.

It has references to earlier works on the subject, index to scientific names and glossary of botanical terms used in descriptions.

The book is printed on fine art paper, but this has resulted in unjustified wastage of paper space after each description. With careful layout, at least one-third of the printed pages could have been saved. These days, printing of coloured plates has become quite a costly affair, however, the price at Rs. 1,200/- is a little steep for this book.

■ M.R. ALMEIDA

2. A BIBLIOGRAPHY OF THE PLANT SCIENCE OF NEPAL (Supplement 1) by Keshab R. Rajbhandari. Published by The Society of Himalayan Botany [University Museum, University of Tokyo, Hongo 7-3-1, Tokyo 113-0033, Japan], 2001. Pp. i-xiii + 1-160 (25.5 x 18 cm). Price not mentioned.

This is a supplement to the bibliographic book published in 1994 on the plant science of Nepal. It gives the titles published during the last 6 years.

The first 78 pages of the supplement contain alphabetical entries arranged in the following order: author names followed by titles and publication data. The remaining 82 pages contain the subject index and index to scientific names of plants (with cross references to authors in the alphabetical bibliography).

As stated by Samar Bahadur Malla in his foreword, documentation is a vital pillar in scientific research and technological development, and I am sure this Supplement will be useful in the study of plant wealth of Nepal.

■ M.R. ALMEIDA

3. AROMATIC AND MEDICINAL PLANTS – YIELDING ESSENTIAL OIL FOR PHARMACEUTICAL, PERFUMERY, COSMETIC INDUSTRIES AND TRADE by M.P. Shiva, Alok Lehri and Alka Shiva. Published by International Book Distributors, 9/3, Rajpur Road, Dehra Dun, Uttaranchal, 2002. Pp. i-viii + 1-341 (24 x 18 cm), with 12 line-drawing plates and 20 colour photographs. Price Rs. 1,950.00 or $ 65.00.

The book mainly deals with aromatic plants, so its title "Aromatic and Medicinal Plants" is somewhat misleading. As ascertained by J.K. Rawat, Director of Forest Research Institute, the book describes 60 aromatic plants.

The following subjects are discussed under each plant description: 1. Origin and

History, 2. Habit, 3. Morphology, 4. Phenology, 5. Distinguishing field characters, 6. Distribution, 7. Access and vulnerability, 8. Climate, 9. Soil types, 10. Silvicultural requirements, 11. Silvicultural characters, 12. Propagation, 13. Harvesting, 14. Grading and processing, 15. Storage, 16. Value addition, 17. Substitutes and adulterants, 18. Physico-chemical properties, 19. Active principles, 20. Production, 21. Uses, 22. Marketing and trade channels, 23. Export, 24. Recommendation and future vision, 25. References.

There is a lack of good books on aromatic plants of India. But in my opinion this book is far below the required standard for such books. Many important aromatic plants are missing which makes the scope of the book very limited. Some of the important aromatic plants missing are: *Murraya koenigii*, *Bothriochloa odorata*, *Capillipedium asimilis*, *Canarium strictum* and *Vateria indica*.

Many references are incomplete and one wonders if the authors have referred to the publications cited or taken the information from secondary sources, e.g. Bacon (1909): Philipp. J. Sci. 4A, 131. (p. 100); Gupta (1964): Ind. Forester 90 - pp. 459 (p. 134)

Both the references do not give the initials of the author's name. The second reference mentions pp. (pages) and gives only one page 459.

The manuscript has not been properly read before publishing it. Under "Vanilla" the botanical name *Vanilla periflora* Andr. with synonym *V. fragrans* Ames is listed, but the title of the figure (not so good) is given as *Vanilla planifolia* Andr. The author of the Tropical American orchid *Vanilla planifolia* is Jackson (not Andrews). The availability of these two *Vanilla* species in the wild as mentioned by the authors requires validation.

All the species appear randomly in the book with no specific system being followed. In some places, the order of appearance has been based on English names like Mint, Patchouli, Rosemary, Saffron, Sandalwood; while in the case of Ajowan, Ajmod, Am(b)a-haldi, etc. they have been arranged according to their Hindi names, while in still others like *Matricaria chamomilla* they have been arranged according to their scientific names. This has resulted in species of the same genera being separated by a number of pages. (e.g. *Curcuma amada* on p. 30 and *C. aromatica* on p. 314; *Cymbopogon citrates* on p. 204, *C. jwarancusa* on p. 177 and *C. nardus* on p. 110 all arranged according to English names).

The Index lists some dubious names like *Abelmoschus agallocha* (p. 13). This name perhaps refers to *Aquillaria agallocha*.

Cymbopogon nardus Rendle has been cited as a synonym under *C. winterianus* Jowitt (see p. 110). However, these two grasses are distinct species (not conspecific). *Cymbopogon winterianus* Jowitt is a grass having lower glume with three definite intracarinal nerves, while typical *C. nardus* (L.) Rendle is without them. If due to some reason (e.g. due to variability to a great extent) these two species happen to be the same (as they both originally come from Sri Lanka) *Cymbopogon nardus* (L.) Rendle has priority and should be the correct name of this grass. Incidentally, native Indian grass cultivated in Tamil Nadu and elsewhere in the country is *Cymbopogon nardus* (L.) Rendle var. *confertiflorus* (Steud.) Stapf ex Bor.

The authors do not seem to be aware of the International rules on botanical nomenclature. For example: *Acorus calamus* (L.) *Syzygium aromaticum* (L.) *Citrus limon* (L.). When the author(s) name is cited in parenthesis it should always accompany the name(s) of the other author(s) outside the parenthesis. The name in the bracket indicates that the species was first published under another generic name, while the name outside parenthesis indicates the author who placed the taxon in its proper taxonomic binomial position. I do not wish to quote other nomenclatural errors in the book. It would suffice here if we agree that no matter how much information you gather, if it is reported under an erroneous name it will serve no purpose.

The photograph of *Coleus aromaticus* (now *Solenostemon amboinicus*) has been wrongly labeled as *Trachyspermum ammi* (Ajowan).

The book lacks a good index. The species index on p. 339 includes 111 binomials (including some synonyms); a number of specific names dealt in the book are missing in the index. *Carum copticum* given as p. 81 in the index is present on p. 23 (not given in the index) under synonyms of *Trachyspermum ammi* (L.) Sprague.

Considering the secondary information provided in this book, which can be retrieved from volumes of WEALTH OF INDIA among other books, the price of the book at Rs. 1,950/- is not justifiable by any standard.

■ M.R. ALMEIDA

4. RAPTOR WATCH: A GLOBAL DIRECTORY OF RAPTOR MIGRATION SITES

Compiled and edited by Jorje I. Zalles and Keith L. Bildstein, 2000. BirdLife Conservation Series No. 9, BirdLife International, Cambridge, U.K. Pp. 419, 22 black and white photos, 21 tables, 21 figures, 3 appendices (24 x 17 cm). $ 58.00.

A global conservation undertaking was kick-started in 1988 called 'Hawks Aloft Worldwide'. More than 800 raptor biologists and conservationists worldwide in more than 100 countries on six continents provided information on known and potential raptor migration sites. This compendium is based on the information submitted, and provides the information in a readable, accessible manner.

The Introductory Chapters mention species of global conservation concern as listed by BirdLife International, the regional origin of breeding populations of migratory species, countries with taxa that are of conservation importance, and continental distribution and migration status (full vs. partial vs. irruptive migrants) of all migratory species. In the 'Global Analyses' Chapter, one is told that at least 183 (62%), and possibly 193 (67%) of the world's 294 species of raptors engage in seasonal migration. This involves full migrants 19 species (6% of all raptors) in which at least 90% of all individuals leave the breeding area during the non-breeding season. Around 100-104 species (approximately 34%) are partial migrants, some of which range between breeding and non-breeding areas. Local or altitudinal migrants comprise 43-60 species (15% plus), their movements triggered by food availability or local weather conditions. Asia has the highest number (66) of migratory raptor species followed by Africa (61). Furthermore, 28 (37%) of the world's 75 Near Threatened, Vulnerable, Endangered and Critically Endangered raptors are known migrants. Their protection, which involves international networking, co-operation, combined political will and the generation of long term data bases, will prove to be a difficult, protracted, but challenging task.

We are informed that 388 raptor migration watch sites have been identified worldwide, 252 occurring in protected areas. Furthermore, each observation or watch site that has annually recorded a minimum of 10,000 migratory raptors is collectively tabulated. The book contains sufficient information for the reader to decide where to go to observe migratory raptors, or where a species is most likely to be seen.

The main part of the book consists of country and watch site descriptions under regional headings such as Africa; Asia, the Middle East, Australia and the Pacific Islands; Europe; South America, Central America, the Caribbean and Mexico; North America. Country descriptions contain information on the size (sq. km), length of coastlines, neighbouring countries, human population size and growth rate, per capita GNP, major land-use patterns, whether party to International Wildlife Law (UNESCO, Ramsar Convention and CITES), biogeographical provinces, and total number of migratory raptors (full and partial migrants). The watch site descriptions are extensive, providing facts on location with coordinates, altitude, biogeographic province, site description, land tenure, protection status, land use, various threats if any, migration monitoring activity, main migratory periods, regular migratory raptor species, research and conservation activities undertaken, list of contacts and resource personnel for the site, and criteria for inclusion of the site in the global directory.

A large country like North America has 129 watch sites, China 5, a small country like Israel 8, and India, sadly none. Smaller countries like Indonesia have 7, Japan 6, Malaysia 2 and Nepal 2 watch sites respectively. Raptor migration in India is poorly known and little information exists, for example, on the lesser kestrel and Amur falcon, which migrate through India in huge numbers. The book highlights the lack of information on Autumn and Spring migration over the Indian Himalaya. Raptors migrate on a broad front of 1,000 km over the Himalaya, but watch sites need to be identified and established where climate and geography create conditions and 'corridors' in the form of N-S oriented river valleys such as the upper Kali Gandaki in Nepal.

Appendix 1 lists major National (US) and International raptor organizations and Appendix 2 cites countries that have ratified the convention on biological diversity (CBD). The last eight pages are an Index of migratory raptors at Raptor Watch Global Directory (RWGD) watch sites with keys to migratory status, two-letter country codes and names for different watch sites and number of watch sites at which a particular species occurs.

In conclusion, RAPTOR WATCH is well-produced, both in content and production that took over 10 years to complete. An ambitious and pioneering project, it has great conservation potential through setting in motion conservation efforts and tourism promotion for watching migrating birds of prey. For example, more than 90,000 enthusiasts visit Hawk Mountain Sanctuary in North America annually. The book provides quick reference on the distribution and conservation status, highlights areas/countries where intensive work is required and addresses pressing problems. It will help develop monitoring programmes to track migrating raptor populations and determine fluctuations and causes over a long term period. Besides promoting further research, it should help to motivate greater international collaboration in raptor conservation. The book would also encourage serious raptophiles to witness the spectacle of migration and experience wild raptors at close quarters as volunteers through trapping and banding programmes. Before migrating raptors can be protected, we need to know where, when and how they migrate. This book is the first step in that direction.

■ RISHAD NAOROJI

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MISCELLANEOUS NOTES

1. THE HARVARD COLLECTION OF SOUTH ASIAN MAMMALS

Founded in 1859, the Museum of Comparative Zoology (MCZ) at Harvard University in Cambridge, Massachusetts, possesses the oldest systematic mammal collection in the United States. While not ranked among the larger mammal collections in terms of number of specimens housed, the Mammal Department of the MCZ stands as one of the most complete collections in the world, in terms of taxa represented in its holdings.

In a recent review of South Asian mammals in the collection of the MCZ, we have identified more than 700 specimens representing 160 different species from the South Asian region (here taken to include Pakistan, India including the Andaman and Nicobar Islands, Sri Lanka, the Maldives, Nepal, Bhutan, Bangladesh and Upper Myanmar). The species represented are listed in Table 1. The intention is to inform researchers, especially those in the South Asian

Table 1: List of mammal species from South Asian localities in the Museum of Comparative Zoology at Harvard University

Insectivora	
Hemiechinus collaris	Indian long-eared hedgehog
Hemiechinus micropus	Indian (Pale) hedgehog
Crocidura horsfieldi	Horsfield's shrew
Suncus etruscus	White-toothed pygmy shrew
Suncus montanus	Sri Lanka highland shrew
Suncus murinus	Asian house (Grey musk) shrew
Suncus stoliczkanus	Anderson's shrew
Nectogale elegans	Elegant water shrew
Soriculus caudatus	Hodgson's brown-toothed shrew
Soriculus nigrescens	Himalayan shrew
Euroscaptor micrura	Himalayan (Eastern) mole
Scandentia	
Tupaia belangeri	Northern (Malay) tree shrew
Chiroptera	
Pteropus giganteus	Indian flying fox
Pteropus melanotus	Black-eared flying fox
Rousettus leschenaulti	Leschenault's rousette (Fulvous fruit bat)
Rhinopoma hardwickei	Lesser mouse-tailed bat
Rhinopoma microphyllum	Greater mouse-tailed bat
Saccolaimus saccolaimus	Naked-rumped pouched bat
Taphozous longimanus	Long-winged tomb (Longarmed sheathtail) bat
Taphozous melanopogon	Black-bearded (Bearded) sheathtail bat
Taphozous nudiventris	Naked-rumped tomb bat
Megaderma lyra	Greater (Indian) false vampire bat
Megaderma spasma	Lesser false vampire bat
Rhinolophus ferrumequinum	Greater horseshoe bat
Rhinolophus lepidus	Blyth's horseshoe bat
Rhinolophus rouxi	Rufous horseshoe bat
Hipposideros atra	Dusky roundleaf bat
Hipposideros fulvus	Fulvus roundleaf bat
Hipposideros lankadiva	Indian roundleaf bat
Hipposideros pomona	Pomona roundleaf bat
Hipposideros speoris	Schneider's roundleaf bat
Kerivoula picta	Painted bat

Table 1: List of mammal species from South Asian localities in the Museum of Comparative Zoology at Harvard University (*contd.*)

Eptesicus nasutus	Sind bat
Myotis longipes	Kashmir cave bat
Myotis muricola	Whiskered myotis
Myotis mystacinus	Whiskered (Mustachioed) bat
Pipistrellus affinus	Chocolate pipistrelle
Pipistrellus ceylonicus	Kelaart's pipistrelle
Pipistrellus coromandra	Indian pipistrelle
Pipistrellus mimus	Indian pygmy pipistrelle
Pipistrellus paterculus	Mount Popa pipistrelle
Scotoecus pallidus	Desert yellow bat
Scotophilus heathi	Greater Asiatic (Common) yellow bat
Scotophilus kuhli	Lesser Asiatic yellow bat
Tylonycteris pachypus	Lesser bamboo bat
Harpiocephalus harpia	Hairy-winged bat
Murina cyclotis	Round-eared tube-nosed bat
Miniopterus pusillus	Small bent-winged bat
Miniopterus schreibersi	Schreibers's long-fingered bat
Primates	
Nycticebus coucang	Slow loris
Macaca mulatta	Rhesus macaque
Macaca silenus	Liontailed macaque
Macaca sinica	Toque macaque
Semnopithecus entellus	Hanuman (Common) langur
Trachypithecus johni	Hooded leaf monkey (Nilgiri langur)
Trachypithecus phayrei	Phayre's leaf monkey
Trachypithecus vetulus	Purple-faced leaf monkey
Hylobates hoolock	Hoolock gibbon
Carnivora	
Canis aureus	Golden jackal (Jackal)
Cuon alpinus	Dhole
Vulpes vulpes	Red fox
Catopuma temmincki	Asiatic golden cat
Felis chaus	Jungle cat
Neofelis nebulosa	Clouded leopard
Panthera pardus	Leopard
Panthera tigris	Tiger
Uncia uncia	Snow leopard
Herpestes edwardsi	Indian grey (Common) mongoose
Herpestes javanicus	Javan (Small Indian) mongoose
Herpestes smithi	Ruddy mongoose
Herpestes urva	Crab-eating mongoose
Hyaena hyaena	Striped hyena
Amblonyx cinereus	Oriental small-clawed (Clawless) otter
Lutra lutra	European (Common) otter
Arctonyx collaris	Hog badger
Martes flavigula	Yellow-throated marten
Mustela sibirica	Siberian (Himalayan) weasel
Ailurus fulgens	Red panda
Melurus ursinus	Sloth bear
Ursus arctos	Brown bear
Ursus thibetanus	Asiatic (Himalayan) black bear

Table 1: List of mammal species from South Asian localities in the Museum of Comparative Zoology at Harvard University (*contd.*)

Paguma larvata	Masked (Himalayan) palm civet
Paradoxurus hermaphroditus	Asian palm civet (Toddy cat)
Paradoxurus zeylonensis	Golden palm civet
Viverricula indica	Small Indian civet
Cetacea	
Platanista gangetica	Ganges river (Gangetic river) dolphin
Platanista minor	Indus river dolphin
Sirenia	
Dugong dugon	Dugong
Proboscidea	
Elephas maximus	Asiatic (Indian) elephant
Perissodactyla	
Equus kiang	Kiang (Asiatic wild ass)
Rhinoceros unicornis	Indian (Great Indian one-horned) rhinoceros
Artiodactyla	
Sus scrofa	Wild boar
Sus salvanius	Pygmy hog
Moschiola meminna	Indian spotted chevrotain
Moschus chrysogaster	Alpine musk deer (Musk deer)
Axis axis	Chital
Axis porcinus	Hog deer
Cervus duvaucelii	Barasingha (Swamp deer)
Cervus elaphus	Elk (Kashmir stag)
Cervus eldii	Eld's deer (Thamin)
Cervus unicolor	Sambar
Muntiacus muntjac	Indian muntjac
Antilope cervicapra	Blackbuck
Gazella bennettii	Indian gazelle
Bos frontalis	Gaur
Bos grunniens	Yak
Boselaphus tragocamelus	Nilgai
Bubalus bubalis	Water (Wild) buffalo
Budorcas taxicolor	Takin
Tetracerus quadricornis	Four-horned antelope (Chowsingha)
Capra falconeri	Markhor
Capra sibirica	Siberian ibex (Ibex)
Hemitragus hylocrius	Nilgiri tahr
Hemitragus jemlahicus	Himalayan tahr
Nemorhaedus sumatrensis	Serow
Ovis ammon	Argali (Great Tibetan sheep)
Ovis vignei	Urial
Pseudois nayaur	Bharal
Pholidota	
Manis crassicaudata	Indian pangolin

Table 1: List of mammal species from South Asian localities in the Museum of Comparative Zoology at Harvard University (*contd.*)

Rodentia	
Callosciurus erythraeus	Pallas's squirrel
Callosciurus pygerythrus	Irrawaddy (Hoarybellied Himalayan) squirrel
Dremomys lokriah	Orange-bellied Himalayan squirrel
Funambulus palmarum	Indian (Threestriped) palm squirrel
Funambulus pennanti	Northern (Fivestriped) palm squirrel
Funambulus sublineatus	Dusky palm squirrel
Funambulus tristriatus	Jungle palm squirrel
Marmota himalayana	Himalayan marmot
Menetes berdmorei	Indochinese ground squirrel
Ratufa bicolor	Black (Malayan) giant squirrel
Ratufa indica	Indian giant squirrel
Ratufa macroura	Sri Lankan (Grizzled) giant squirrel
Tamiops macclellandi	Himalayan striped squirrel
Hylopetes alboniger	Particoloured flying squirrel
Hylopetes fimbriatus	Kashmir flying squirrel
Petaurista petaurista	Red (Common) giant flying squirrel
Petaurista philippensis	Indian giant (Large brown) flying squirrel
Alticola montosa	Central Kashmir vole
Hyperacrius fertilis	True's vole
Microtus sikimensis	Sikkim vole
Meriones hurrianae	Indian desert jird (gerbil)
Tatera indica	Indian gerbil
Apodemus rusiges	Kashmir field mouse
Bandicota indica	Greater bandicoot rat
Bandicota bengalensis	Lesser bandicoot rat (Indian mole-rat)
Golunda ellioti	Indian bush rat
Millardia meltada	Soft-furred rat (Metad)
Mus booduga	Little Indian field mouse
Mus mayori	Mayor's mouse
Mus musculus	House mouse
Mus terricolor	Earth-coloured mouse
Nesokia indica	Short-tailed bandicoot rat
Niviventer eha	Smoke-bellied rat
Rattus nitidus	Himalayan field rat
Rattus rattus	House rat
Rattus turkestanicus	Turkestan rat
Srilankomys ohiensis	Ohiya rat
Platacanthomys lasiurus	Malabar spiny dormouse
Hystrix indica	Indian crested porcupine
Lagomorpha	
Ochotona roylei	Royle's pika (Himalayan mouse-hare)
Ochotona thibetana	Moupin pika

region, of the availability of good series of many different species in the collections of the MCZ. Recourse to the collection will assuredly serve future investigations of systematics and of current and historical patterns of mammalian distribution in the region.

The collection is historically an important one. Specimens purchased from H.A. Ward and E. Gerrard Jr. formed the original basis of the South Asian collection at the MCZ. Collectors such as W. Theobald, M. Carleton, and C. Carpenter continued to add to this collection during the 1860s and 1870s with their donations of large natural history collections from India. Another period of significant growth in accessions from South Asia, especially of bats and primates, occurred under the enthusiastic tenure of the great mammalogist G.M. Allen as Curator of the MCZ, Mammal Department (during 1924-1942). More recent additions to the collection have included specimens procured during expeditions to Nepal and Pakistan in the 1950s.

There is one name-bearing type series of a South Asian mammal at the MCZ — the holotype and paratype of *Pteropus ariel* (= *P. giganteus ariel*) described by G.M. Allen (1908) from the Maldives (see Helgen and McFadden, 2001:141). The department holds topotypes of many mammalian taxa from the region, including *Budorcas taxicolor*, *Capra falconeri cashmiriensis*, *Soriculus caudatus*, *S. nigrescens*, *Niviventer niviventer monticola*, *Niviventer eha* and *Miniopterus pusillus*. Additionally, the collection also contains specimens of a large number of South Asian mammals that are rarely collected.

In the list, taxonomy follows Wilson and Reeder (1993); common names follow Wilson and Cole (2000); where these names deviate from Prater (1948), that author's common names are given in parentheses.

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2. LITTLE GREBE *TACHYBAPTUS RUFICOLLIS*: AN ADDITION TO THE AVIFAUNA OF LADAKH

On the morning of July 1, 1999 between 1000 and 1030 hrs, three adult little grebe *Tachybaptus ruficollis* in summer plumage were observed at Trishul Tso, a small lake created by the Army, near the headquarters of the Ladakh Scouts on the Leh-Srinagar road. The birds were immediately recognised as little grebe *Tachybaptus ruficollis*, a species familiar to the observers. On July 3, 1999 only one bird was recorded at the lake. HSS checked for the birds again at the lake on July 9, 1999, but none were sighted.

There are no previously documented records of little grebe from Ladakh to the best of our knowledge. Ali and Ripley (1981), Grimmett *et al.* (1998) and Kazmierczak and van Perlo (2000) do not mention this area in the species' distribution.

Jayson, E.L. *et al.*: *Fregata ariel* Gray PLATE 1

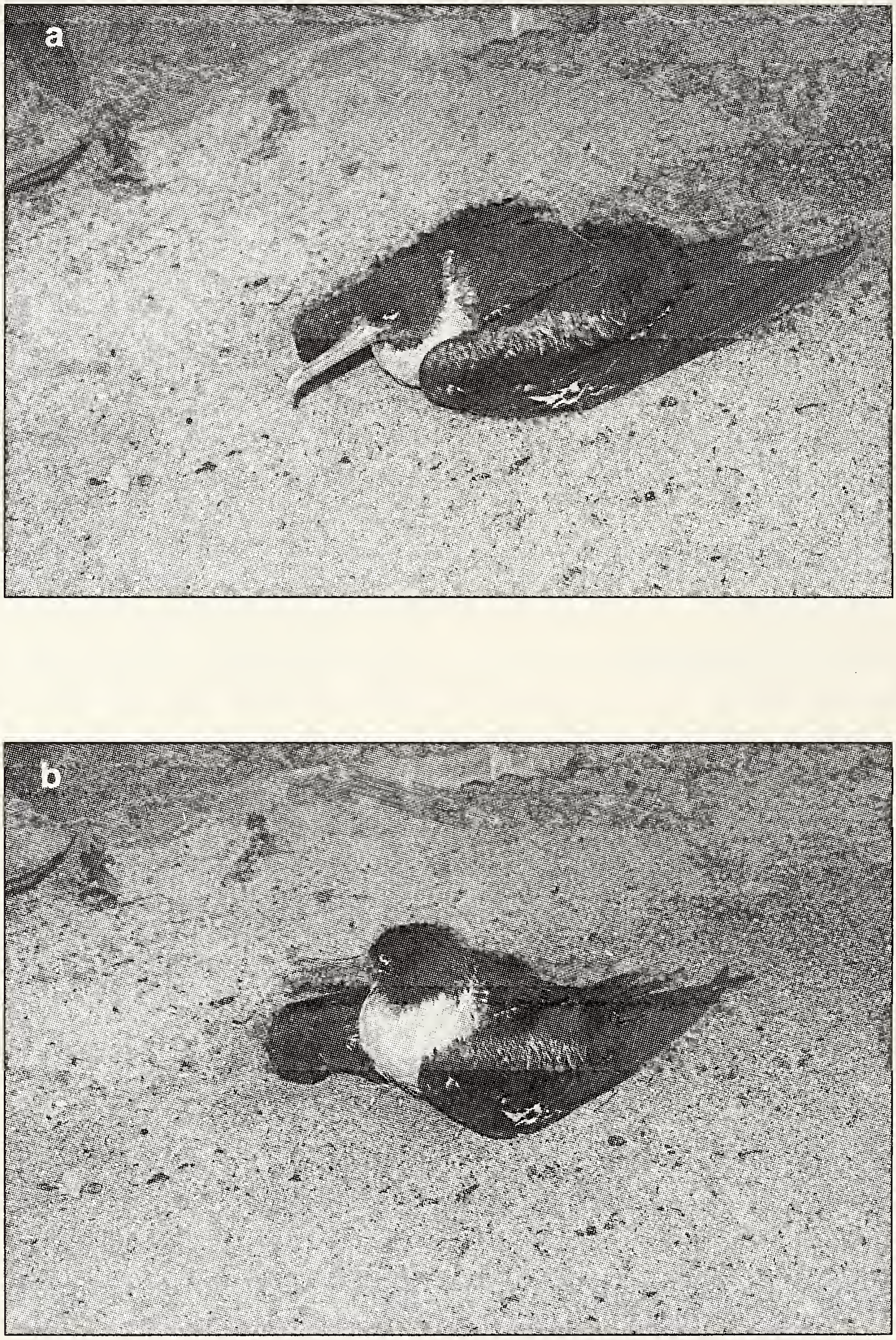

Fig. 1a-b: Lesser frigatebird *Fregata ariel* Gray in the Kole wetlands of Thrissur, Kerala

The upper limit of the species is variously recorded as 1,800 m (Ali and Ripley 1981), 2,500 m (Ali 1996) and 1,372 m (Fleming *et al.* 1984) for the Indian subcontinent. Interestingly, the site where the birds were observed is at an elevation of *c.* 3,500 m, considerably exceeding the record from Rara Lake in Nepal on April 1, 1976 at 3,050 m (Inskipp and Inskipp 1991).

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3. SIGHTING OF LESSER FRIGATEBIRD *FREGATA ARIEL* GRAY IN THE KOLE WETLANDS OF THRISSUR, KERALA

(*With one plate*)

Kole wetland in Thrissur district is one of the important wintering grounds for migratory birds coming to Kerala. The area lies in between 10° 20' - 10° 40' N and 75° 58' - 76° 11' E, extending to about 11,000 ha. Kole wetlands are situated below sea level and paddy is cultivated during the months of October to April, after draining water. During monsoon (June to September) the whole area is inundated. As a part of ecological studies on wetland birds initiated in 1998, we have been surveying the area regularly. During the period, a lesser frigatebird *Fregata ariel* Gray was recorded from Guruvayur, Thrissur district on June 16, 2000. The place is situated on the west coast and is about 4 km away from the sea. Local people noticed a live bird and brought it to the Thrissur Zoo. On examination, the bird was identified as an adult female of the lesser frigatebird. The bird had a black head and red eye rings, black throat and white breast extending into a complete collar around the neck. The bird stayed alive for a week in the zoo, after which it was skinned and preserved.

Only a few sighting details of the lesser frigatebird are reported from Kerala State. Ferguson and Bourdillon (1904) recorded it from Trivandrum. Ali (1984) has not reported the species from Kerala. Faizi (1985) reported the species from Quilon, based on a museum specimen. This is the first report of the species from central Kerala and also from the Kole wetlands of Thrissur. The individual seems to be an accidental straggler that landed in the coastal zone due to the heavy monsoon winds prevalent in June.

November 25, 2000

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4. INDIAN POND-HERONS *ARDEOLA GRAYII* FEEDING ON DRAGONFLIES

Following the failure of monsoon in our area in 1999-2000, Rishi Valley (Chittoor district, Andhra Pradesh) wore a drab look with the drying up of ponds and other waterbodies. Even the percolation tank, which usually harbours water even in the lean period, was reduced to a muddy puddle.

I was out on a walk along the road lined with trees such as *Ficus* and *Spathodea* outside the school campus, on the evening of March 5, 2000, when I noticed three Indian pond-herons (*Ardeola grayii*) perched on a banyan tree *Ficus bengalensis*, *c.* 8 m above the ground. It was too early for them to roost and there was no major disturbance that might have forced them to fly to a tree. I paused to look around, and within a few minutes was able to find the reason.

Just above the Indian pond-herons was a small group of dragonflies, flying close to the foliage of the banyan tree. Even as I was watching them, an Indian pond-heron attempted to snap at a dragonfly that was just a few inches above it. This and the attempts that followed were all unsuccessful for the few minutes that I observed them. A little later, the dragonflies moved away from the tree and the Indian pond-herons flew to forage in the dry, barren fields. A few days later, I noticed another Indian pond-heron on a tamarind tree outside my house attempting to catch dragonflies in flight.

With the disappearance of waterbodies, the Indian pond-herons had to change their foraging strategies and had taken to vantage points on trees to catch dragonflies. A few others were seen stalking insects in dry fields and, following cattle and goats just like cattle egrets (*Bubulcus ibis*) which were also occasionally seen with the herons. I had, on an earlier instance, noticed Indian pond-herons attempting to catch dragonflies from the ground at Adyar Estuary in Chennai when the insects were flying low over the islets and water. Prasad and Hemanth (1992; *JBNHS 89*: 246) have reported Indian pond-herons perched on a 7 m willow tree in Bangalore, feeding on bees that came to the flowers. Jose noticed (1999; *NLBW 39(2)*: 39) cattle egrets feeding on insects visiting flowerheads of mango *Mangifera indica* and *Carissa* trees. These observations show how birds adapt their behaviour to changed circumstances to survive.

April 16, 2000

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5. VARIATION RECORDED IN THE IRIS, BILL, LEG AND FOOT COLOURATION IN CATTLE EGRET *BUBULCUS IBIS*

A nesting colony of cattle egret *Bubulcus ibis* was spotted at Zila Garden, Rajkot. They started nesting during early June, 2000. During regular observations, I recorded variations in four birds of the colony. The iris and bill colour of all the breeding birds in the colony was golden yellow, but in these four birds, the iris was red and bill reddish-violet. This variation among breeding populations of cattle egret has not been recorded by Ali and Ripley (1987), Heinzel *et al.* (1973), and Sonobe and Usui (1993).

The breeding birds had pink legs and feet, while the non-breeding birds had black legs and feet. The actual changing of colours was not recorded. (The author has submitted photographic evidence of the observations — Eds.)

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6. RECORD OF A NESTING COLONY OF PAINTED STORK *MYCTERIA LEUCOCEPHALA* AT MAN-MARODI ISLAND IN THE GULF OF KUTCH

(*With one text-figure*)

Gujarat is well endowed with nesting sites of painted stork *Mycteria leucocephala*, both in the vicinity of freshwater inland wetlands and on the coast. Dharmakumarsinhji (1955) observes that these birds nest "more numerously on the coastal areas where marine food is easily available". However, very little is known about the coastal nesting grounds of the painted stork in Gujarat, with the exception of the heronries at Bhavnagar that have been well documented by Parasharya and Naik (1990). In this note, I wish to record the existence of a large nesting colony of painted stork on the Man-Marodi Island in the Gulf of Kutch. This site was studied while I was accompanying teams of students from the Centre for Environment Education, Ahmedabad, to the Sundervan campsite at Beyt Dwarka during 1999-2000.

Man-Marodi is a rocky island quite close to the coast, off Positra, near the mouth of the Gulf of Kutch (Fig. 1). The island itself appears as a large block of rocks some 2-3 sq. km in area, rising at least 20 m above the level of the water. The chief vegetation on this island is scrub and small trees such as *Acacia* and *Salvadora*, interspersed by dense stands of *Euphorbia*. On a first visit to Man-Marodi on October 20, 1999, at least 100 nests of painted stork were observed. Most of the nests had 1 or 2 chicks. The nestlings were in an advanced stage, possibly a month old as suggested by the colour of their plumage and bill, indicating that nesting activity at this site must have started in end August i.e. towards the end of the monsoon. Since the principal vegetation of the island is quite short, most of the nests were observed at *c.* 1.5 m above ground

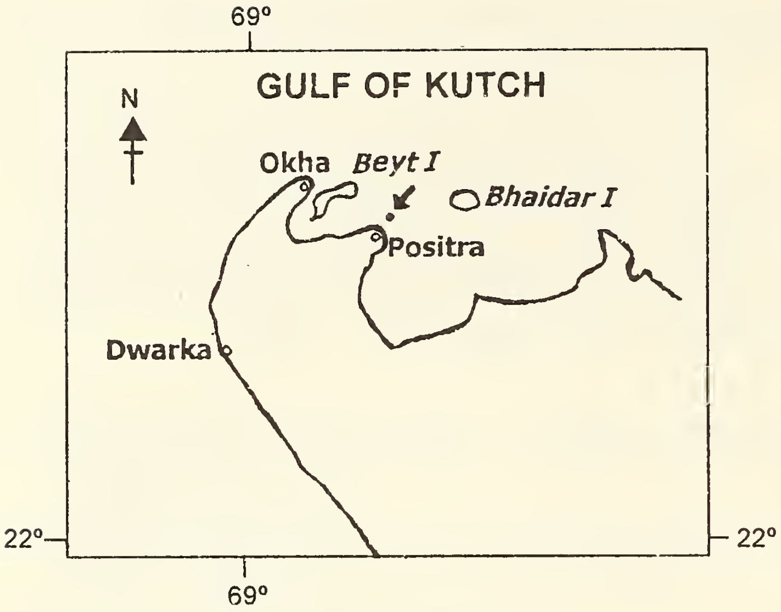

Fig. 1: Map of Man-Marodi Island (Indicated by arrow) in the Gulf of Kutch

level and quite closely packed. Interestingly, some nests were made by stacking sticks and twigs on *Euphorbia* stands. On November 30, 2000, when this island was visited again, no painted storks were seen, although information gathered from local fishermen revealed that the birds had nested during that year too.

This heronry has, of course, not gone unnoticed. In his exhaustive review on the birds of Gujarat, Khacher (1996) refers to Man-Marodi without actually naming it when he writes, "There is an unusual nesting colony of the painted stork on a sandstone island in the Gulf of Kachchh". Possibly, what makes Man-Marodi unusual is that out here, in the absence of true thermals in the sea, painted stork appear to take advantage of the wind hitting the rock face, which creates the effect of thermals and enables the birds to soar in the sky and gain altitude when embarking on food finding missions (Lavkumar Khacher, *pers. comm.*). The use of *Euphorbia* as a nesting substrate is another interesting feature of this heronry.

Why is this island preferred by large numbers of painted stork for nesting? Firstly, the closely packed vegetation affords a good substrate for nesting in colonies. Secondly, the Island being surrounded by the sea on all sides and not being visited by humans too frequently, the birds probably find it to be a safe place. But having said this, I may also mention the problems. For instance, common crows take their toll on painted stork eggs. Reportedly, jackals sometimes visit this island, swimming across from the mainland or from the neighbouring islands during low tide, and can pose a danger for the nestlings. Thirdly, although no humans are known to inhabit this island as of now, local fishermen sometimes anchor their boats in the vicinity of Man-Marodi and reportedly, poach upon the nestlings.

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7. FIRST SIGHTING OF LESSER ADJUTANT-STORK *LEPTOPTILOS JAVANICUS* FROM SANJAY GANDHI NATIONAL PARK, MUMBAI

A solitary adult lesser adjutant-stork *Leptoptilos javanicus* was sighted at Vihar lake, Sanjay Gandhi National Park (SGNP), Mumbai, on January 21, 2001 at 1000 hrs. When first sighted, the bird was searching for food at the bank of the lake. However, due to human disturbance, it took off, soared for a while, settled on a bare tree for 10 min and then resumed its feeding activities. While in the air, it was mobbed by three black kites *Milvus migrans*. However, the bird looked undeterred by these raptors. Subsequently, local birdwatchers sighted it thrice in six days, the last being on January 27, 2001.

According to Ali and Ripley (1987), *L. javanicus* is resident, nomadic (during monsoon) and locally migratory. Apart from Assam, which is its stronghold, it is scattered across West Bengal, Bihar, Orissa, Kerala, Tamil Nadu, Andhra Pradesh, Uttar Pradesh, Delhi, Kutch, Rajasthan, Nepal, Sri Lanka and Bangladesh. Lainer (1999) and Choudhury (1995) have also reported the bird from Goa and Arunachal Pradesh respectively. Though widely distributed, it occurs in very low densities along its entire range except Assam, and has been designated as a 'globally threatened species' (del Hoyo *et al.* 1992; Grimmett *et al.* 1998).

The breeding season of *L. javanicus* stretches from July to January (Grimmett *et al.* 1998) and thus the appearance of an adult bird at SGNP in January indicates that it might be breeding in northern regions of the Western Ghats. The poor monsoon during 2000 and the subsequent water scarcity may also have forced individuals to travel greater distances in search of food. A detailed study of its probable range is, however, essential to be able to comment on its breeding in northwestern Maharashtra.

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8. BLACK IBIS *PSEUDIBIS PAPILLOSA* FEEDING ON FROGS FROM CRAB HOLES

On November 5, 6 and 8, 1999, at about 0700 hrs on the K. Sathanur Road, Kalaignar Karunanidhi Nagar, Trichy, Tamil Nadu, I saw a pair of black ibis *Pseudibis papillosa* running into shallow rainfed pools and beating their wings. Only on November 9, on closer examination, did I realise that the splashing of water and beating of wings, probably by the same pair, had frogs jumping out of the water into crab holes, situated on the margin of the dried portion of the pool. The crab holes were freshly formed. The ibis would thrust their in-curved bills fully into the crab holes, only the warts on their head visible, spreading out their muddy red legs and pull a frog out in *c.* 1-2 min. Once the bird had pulled the frog out, it would throw it on the ground, stab it with its bill and then eat it. One bird ate about 10 frogs in 23 min in this manner. Tadpoles that jumped out and hid within the hexagonal cracks of the dried patches of loam were not eaten by the ibis. I have seen black ibis infrequently in Trichy. They do not breed around here.

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9. NOTE ON BREEDING OF ANDAMAN TEAL *ANAS GIBBERIFRONS* IN SOUTH ANDAMAN ISLANDS, INDIA

The Andaman teal *Anas gibberifrons* occurs in the Andaman Islands and Great Cocos Islands. The species is not globally threatened, but is considered 'threatened' in the Andaman Islands because of agricultural development and disappearance of wetlands (Andrews and Whitaker 1994; Vijayan *et al.* 2000). However, very little information was available on its status and population until recently (Vijayan 1996; Vijayan and Sakthivel 1996; Vijayan *et al.* 2000). We report here an instance of breeding of the Andaman teal from the Mahatma Gandhi Marine National Park (MGMNP), Wandoor in the South Andaman Island.

MGMNP is spread over *c.* 281.5 sq. km and is comprised of 15 islands of the Labyrinth group, along the southwest coast of South Andaman Island. Only 60 sq. km of the Park is covered by landmass and the rest comprises open sea and creeks. The presence of marshy area and creeks in this Marine National Park provides an ideal breeding habitat for the Andaman teal (Harry Andrews *pers. comm.*, Vijayan *et al.* 2000). On May 28, 1999, while looking for sea snake nests in and around the Redskin Island, we approached a small, unnamed islet about 50 to 75 m away from the northeastern coast of Redskin Island. The islet is about 2-3 m high from the high tide line, about 7 m long and 3 m wide. On approaching the islet we flushed two teals, which we later identified as the Andaman teal (*Anas gibberifrons*). We searched the islet and found a neatly placed nest, with nine creamish eggs with small black spots all over, at the base of a small shrub at the northern tip of the islet. The nest was *c.* 20 cm in diameter and consisted of dried grass, thin twigs and down feathers of the adult. The nest was easily accessible to human as well as water monitor lizard (*Varanus salvator andamanensis*). Before landing on this islet, we had sighted a water monitor lizard basking on a small shrub, but it disappeared into the water on our arrival. A little away from the teal nest, four nests of black-naped tern (*Sterna sumatrana*) were noticed. Each of them had one or two eggs that were white with prominent black spots. When we left the islet we saw the parent birds return to the nest. The next day, when we returned to the islet to photograph the nest of the Andaman teal, eight of the nine eggs had hatched and the ninth chick was emerging when we reached. The newly hatched chicks were grey, with a faint white circle around the eyes, and a grey beak. The available definite breeding records to date are from August to October (Ali and Ripley 1983; Vijayan *et al.* 2000).

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10. SOME OBSERVATIONS ON NESTING OF BONELLI'S EAGLE *HIERAAETUS FASCIATUS* (VIEILLOT)

During our regular treks for bird watching, we have observed a rare phenomenon not reported elsewhere. This year, for the third year in succession, the same pair of Bonelli's eagle *Hieraaetus fasciatus* (Vieillot) has nested at the same site, building their third nest on top of the previous two nests. The total height of the nest has now reached a massive 0.9 m; sticks of various trees gathered from the vicinity have been used to build this *c.* 1 m wide nest. The nest is at a height of *c.* 12 m on a jambul *Syzygium cumini* (L.) tree on the slope of Pavangadh, 962 m above msl, 18 km northwest of Kolhapur city, and is lined with fresh green leaves. Nesting at the same site by the same pair is a phenomenon we have not observed in other Bonelli's eagle pairs elsewhere in the surrounding hilly region.

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11. STATUS OF WHITE-BELLIED SEA-EAGLE *HALIAEETUS LEUCOGASTER* IN RATNAGIRI DISTRICT, MAHARASHTRA

The white-bellied sea-eagle *Haliaeetus leucogaster* is thinly, but widely distributed and is listed as vulnerable in the Indian RED DATA BOOK. No data on the status and population of this species is available. Its present status, along the 164 km coastline, in Ratnagiri district, Maharashtra, is given on the basis of a survey undertaken in the district during 1996-97 and 1997-98. We located 62 nests during our survey. The identity of the bird was confirmed from the HANDBOOK.

The species is resident along the seaboard and offshore islands from about 19° N of Mumbai down the west coast and up the east to Bangladesh, Laccadive Is. (now Lakshadweep), Sri Lanka, and Andaman & Nicobar Islands and is vagrant in Gujarat (Ali and Ripley 1978).

We undertook a survey to determine the present status and distribution of the white-bellied sea-eagle in Ratnagiri district, as the species is found throughout the coastline of this district.

Ratnagiri district is situated in the Konkan region of Maharashtra State (16.30°-18.04° N and 73.02°-73.52° E). The coastline of the district is about 164 km long and is uniformly rocky and shallow. Various bluffs and promontories enclose small sandy beaches, interspersed by estuaries of the more important rivers and the mouths of numerous minor streams. Average width of the district is about 64 km. We surveyed the coastal line, which is 5 to 7 km wide.

The Konkan region experiences a hot and humid maritime climate with plentiful rain during the monsoon (June to September ave. 3,000 mm). The mean annual temperature ranges from 22 °C to 30 °C. The mean relative humidity is 80% in the region.

The eagle that affects the seacoast and tidal creeks and estuaries is seen occasionally a few miles inland along tidal rivers and at freshwater lakes (Ali and Ripley 1978).

In our survey, we saw most of the nests along the seacoast, tidal creeks and estuaries. Of the 62 nests recorded, 41 nests were found up to 0.5 km from the seacoast and 20 nests were found from 0.5 km to 2 km. Only one nest was about 7 km away from the seacoast at Gavde Ambere, Ratnagiri taluka along the Purnagad creek.

The nests were located while walking along the coast and collecting information from the locals by showing them pictures from the PICTORIAL GUIDE TO THE BIRDS OF THE INDIAN SUBCONTINENT (Ali and Ripley 1995) and THE BOOK OF INDIAN BIRDS (Ali 1996). All the nests were visited in the nesting season and photographs taken wherever possible.

According to Ali and Ripley (1978), the breeding season is October to January. However, we observed courtship and nest building from mid-September to January. Well-grown chicks were seen in the nest up to the end of March.

Nest size: Most nests located in Ratnagiri district were 1 to 1.5 m wide. At Rohile, Taluka Guhagar the size of a 10 year old nest was 1.7 m x 1.2 m x 0.7 m.

Height: Most nests located were 20-40 m high, in lofty trees. Only one nest was found below 10 m i.e. 7.5 m at Velneshwar, Guhagar taluka (Approximate measurements were taken).

Table 1: Nest height of the white-bellied sea-eagle in Ratnagiri district

	Nest height (m)	No. of nests
1	0 to 10	1
2	10 to 20	15
3	20 to 30	41
4	30 to 40	5

Nest: At Rohile, Guhagar taluka the nest were made of sticks of *Ficus bengalensis*, *Carissa carandas*, *Leea macrophylla*, *Crotalaria verrucosa*, *Loranthus longifolia*, *Bambusa arundinacea* and other unidentified tree species. One nest stick was exceptionally long (86 cm) and thick (2.86 cm).

Pieces of net, plastic paper, bits of woven bag were also used. Green leaves of *Mangifera indica*, *Casuarina equisetifolia*, *Ficus bengalensis*, *Grewia asiaticia*, *Smilax macrophylla*, *Sapindus laurifolius*, *Bombax malabaricum* were used to line the nest.

The nesting trees of the eagle as observed by us are given in Table 2.

Table 2: Tree species used for nesting by *Haliaeetus leucogaster*

		Taluka					
	Tree species	A	B	C	D	E	T
1	*Mangifera indica*	4	0	2	8	6	20
2	*Casuarina equisetifolia*	2	7	5	5	0	19
3	*Ficus bengalensis*	0	0	4	3	2	09
4	*Ficus religiosa*	0	0	3	2	0	05
5	*Cocos nucifera*	0	0	0	1	1	02
6	*Tamarindus indica*	0	0	0	1	1	02
7	*Sterculia foetida*	0	1	0	0	0	01
8	*Terminalia paniculata*	0	0	0	0	1	01
9	*Alstonia scholaris*	0	0	0	0	1	01
10	*Artocarpus heterophylla*	0	0	1	0	0	01
11	*Terminalia bellerica*	0	0	0	0	1	01
	Total	6	8	15	20	13	62

A = Mandangad; B = Dapoli; C = Guhagar; D = Ratnagiri; E = Rajapur; T = Total

Table 3: Alternate nesting sites on same tree

	Place	Nest No	Distance between two nests	Tree species	Activity	
					1996-1997	1997-1998
1	Palshet	20	30 m	*Casuarina equisetifolia*	A	I
2	Palshet	21	-	*Casuarina equisetifolia*	I	A
3	Narvan	26	15 m	*Ficus bengalensis*	A	I
4	Narvan	27	-	*Ficus bengalensis*	I	A
5	Ambuvadi	33	Nest 33 and 34 were connected by sticks	*Ficus religiosa*	A	A
6	Ambuvadi	34	Nest 33 and 34 were connected by sticks	*Ficus religiosa*	I	I

A = Active Nest, I = Inactive Nest

Age: Local enquiry revealed the approximate age of 44 nests out of a total 62 nests as follows: 21 nests of up to 5 years, 6 nests of 5 to 10 years and 10 nests of 11 to 25 years. Seven nests were 26 to 50 years old.

Alternate nesting sites: We observed alternate nesting sites at three places, where both the nests were in good condition, but were used in alternate years. Details are given in Table 3.

Territory: Ali and Ripley (1978) define territory as, "usually a single pair with vast territory, but not uncommonly several pairs and nests on the same island".

In our survey, we have seen two nests distant from each other. At times we have found more than one nest in a small area. We sighted 3 nests (nest no. 17 to 19) in Guhagar, and 3 nests (nest no. 51 to 53) in Kashali village, Rajapur taluka. The nests in both these villages are hardly 1 km apart from each other.

Human-Bird Interaction: At Narvan, locals said that the eagle sometimes take poultry. At Jaitapur, local fishermen said that they get indications from the eagle's calls about availability of fish in the sea and at times also scare the eagle to drop its prey and eat the fish.

Names: Ali and Ripley (1978) give the local name as *Kankan*. It is also referred to as *Sheshari* in other regional (Marathi) books. Besides this we have found some more local names. In Ratnagiri district, this eagle is called as *ghar* (kite) and not *garud* (eagle). The other names used by locals are given in Table 4.

Table 4: Local names of the white-bellied sea-eagle

	Area	Taluka	Local Name
1	Borya, Sakhari	Guhagar	Kakkan Ghar
2	Jaitapur	Rajapur	Kokati Ghar
3	Jaitapur	Rajapur	Sasan Ghar
4	Madban	Rajapur	Sasani Ghar
5	Shirgaon	Ratnagiri	Kakran
6	Burondi	Dapoli	Kegai
7	Narvan	Guhagar	Kucheri Ghar
8	Golap	Ratnagiri	Kuran
9	Ambolgad	Rajapur	Kakar

Hunting: Rare hunting incidents were recorded by the locals. One was on the White Sandy Beach at Ratnagiri, while two birds were killed for sport about 4-5 years ago. In Tavsal, Guhagar taluka one bird was killed for sport.

Mango Trees: Out of 62 nests in the district, 20 nests are on Mango tree *Mangifera indica*. The spraying of insecticides on mango trees and nesting activity of eagles starts in October. Due to fear of attack from eagles the nests are first destroyed and then the spraying is begun. This causes loss of eggs or chicks. Cutting of trees also deprives the bird of suitable large nesting trees.

Nest distribution in Talukas: We surveyed the white-bellied sea-eagle in 5 talukas of Ratnagiri district namely Ratnagiri, Guhagar, Rajapur, Dapoli and Mandangad covering about 164 km of coastal area. Out of 62 nests, there were 20 nests in Ratnagiri, 15 nests in Guhagar, 13 nests in Rajapur, 8 nests in Dapoli and 6 nests in Mandangad.

A summary of the bird's nesting activity is given in Table 5.

Table 5: Summary of activity in 1996-1997 & 1997-1998

	Particulars	Activity in the year	
		1996-1997	1997-1998
1	Total nests observed	58	62
2	Total birds seen	80	67
3	Total chicks seen	20	12
4	Adult birds seen on the nest	49	52
5	Chicks seen on the nest	20	12
6	Number of nests with adult and chicks	15	10
7	Number of inactive nests	03	06

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12. CANNIBALISM IN INDIAN WHITE-BACKED VULTURE *GYPS BENGALENSIS* IN KEOLADEO NATIONAL PARK, BHARATPUR, RAJASTHAN

On May 22, 1997, at 0600 hrs, five Indian white-backed vultures *Gyps bengalensis* and a few crows *Corvus splendens* were observed feeding on a small carcass in the Keoladeo National Park, Bharatpur, Rajasthan. Some crows and four vultures were sitting on the ground close to the carcass waiting for their turn to feed. The carcass appeared to be small in size and could not be seen clearly as it was surrounded by the scavengers. Through the spotting scope, it appeared to be a carcass of a dark coloured bird. On closer approach, we found that it was a dead adult Indian white-backed vulture. It was a fresh half-eaten carcass. After a few hours, by 0930 hrs, the carcass was almost finished.

The Indian white-backed vultures are carrion eaters, which feed mostly on large mammal carcasses (Ali and Ripley 1983). The reason for cannibalism in Indian white-backed vulture is not clear, but it was certainly not due to scarcity of food, as there was an abundant supply of food for vultures in the Keoladeo National Park (Prakash 1999).

This observation was recorded when the vulture mortality was at its peak, at the beginning of the crash in the population of the Indian white-backed vulture.

Cannibalism is observed in many predatory birds such as barn owls *Tyto alba*, short-eared owls *Asio flammeus*, Oriental honey-buzzards *Pernis ptilorhynchus* and some sea birds. We have not come across any reference to cannibalism in the Indian white-backed vulture, hence this observation is worth recording.

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13. WINTERING SITE FIDELITY IN WESTERN MARSH-HARRIER *CIRCUS AERUGINOSUS* (LINN.), IN KEOLADEO NATIONAL PARK, BHARATPUR, RAJASTHAN

The Western marsh-harrier *Circus aeruginosus* is a common winter visitor to the Keoladeo National Park, Bharatpur, Rajasthan (27° 7.6' - 27° 12.2' N and 77° 29.5' - 77° 33.2' E). The Bombay Natural History Society has been carrying out intensive studies on the wintering ecology of the species in the Park since 1996.

Six Western marsh-harriers were studied during the winter of 1999-2000. Four harriers were fitted with radio-transmitters, and two were ringed. One adult female was ringed with a black band on the right leg with 'C' etched on it, and two rings – one each of plastic (orange coloured) and aluminium on the left leg. The rings could be clearly seen with binoculars and telescope from a distance of 100-200 m. The bird was caught on January 20, 2000, in the wetland of Block 'K' of the Park by the Stick and Glue Method, on fish bait. It left for its breeding ground by the end of March 2000. The bird was seen every winter since 1996 in this area and was identified by its peculiar plumage and eye colour, before ringing. It was recorded again in winter in the same area on October 14, 2000.

Site fidelity for breeding grounds has already been recorded in Western marsh-harriers (Witkowski 1989). However, I have not come across any reference on Western marsh-harriers returning to the wintering ground, year after year.

Wintering site fidelity has been recorded in birds. Fischer (1981) found thrashers *Toxostoma* sp. in the same wintering territories for the consecutive year, and Price (1981) recorded greenish leaf-warblers *Phylloscopus trochiloides* returning to the same wintering areas in southern India. Among raptors, Steppe buzzards *Buteo buteo vulpinus* in South Africa, rough legged buzzards *Buteo lagopus* in South Sweden, and common buzzards *Buteo buteo* in Europe have been found returning to the same wintering areas in successive years (Olsson 1958, Newton 1979). One *Buteo buteo* was seen in the same place for eight consecutive winters, and another distinctive bird for twelve winters (de Bont 1952, Schuster 1940).

Birds have been recorded returning to the same territories year after year, both at breeding and wintering grounds, because they are likely to be more successful as they have to spend less time in getting familiarised with the habitat, predators and to some extent food sources. Site fidelity in birds also reflects on the quality of habitat in terms of food and habitat availability.

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14. SOUTHERNMOST RECORD OF EASTERN CALANDRA-LARK *MELANOCORYPHA BIMACULATA* AND SIGHTING OF LESSER KESTREL *FALCO NAUMANNI* FROM MATHERAN, A HILL STATION NEAR MUMBAI

Matheran is situated at *c.* 73° 18' E and 18° 28' N in the Western Ghats and is about 105 km from Mumbai. This tiny hill station has an area of 7.35 sq. km, out of which 3.87 sq. km is reserved forest while 3.48 sq. km is under buildings, plots, tanks, roads etc. It has a maximum elevation of 803 m and an average rainfall of about 7,500 mm. I was in Matheran during the second week of April 2000. During the two day visit, I had the good fortune of sighting the eastern calandra-lark *Melanocorypha bimaculata*, of which this was the southernmost record and the lesser kestrel *Falco naumanni*, a Red Data species. The following is a brief account of the same.

Eastern Calandra-lark
Melanocorypha bimaculata

On April 8, 2000, while returning from Charlotte Lake, a man-made reservoir in Matheran, I spotted a solitary, relatively large member of Alaudidae. It moved hurriedly in the dry leaf litter, along the bank of the lake, stopping intermittently to peck at some edible morsel. The two very distinct features that caught my attention were its broad white supercilium and a black patch on the side of the breast. The tail was short, with a stroke of white on its tip. The bird was well camouflaged against the leafy background. It was noticeably stockier and more upright than the greater short-toed lark *Calandrella brachydactyla*. All the field characteristics pointed at only one candidate – the eastern calandra-lark. Later, on April 9, two more birds were sighted near One-Tree-Hill, the southernmost tip of Matheran. They were foraging in a rocky slope interspersed with dry grass beds. They remained in sight for over

15 min before disappearing behind a ledge.

The HANDBOOK states that *M. bimaculata* is a winter visitor to Kashmir, Punjab, Haryana, Rajasthan, Uttar Pradesh, and an occasional visitor to Kutch. Himmatsinhji (1960) and Tiwari (1993) have also reported the bird from Kutch. According to the HANDBOOK, there is no record of the bird from Maharashtra. However, Grimmett *et al.* (1999) mention its presence up to NW Maharashtra. There is also a confirmed unpublished record of two birds near a waterbody in Nasik dist. (Raha, B. pers. comm. in 1999). The present record is therefore the southernmost one for *M. bimaculata*.

Lesser Kestrel *Falco naumanni*

On the afternoon of April 9, 2000, I saw a bird of prey that had just landed on a barren tree on the rocky slope; 50 m separated the two of us. It was difficult to decipher its identity from that distance, but from the size, it looked like a falcon. On a keener view, it resembled the female of the common kestrel *Falco tinnunculus*.

After preening for a few minutes, the bird began hovering in a typical kestrel-like fashion with short bouts of rapid wing beats interrupted by equally short flights. I needed a closer look to see other characteristics to confirm my initial identification. The bird glided in my direction and was below me, providing a dorsal view. The flight was definitely less laboured than that of the common kestrel. Just when I was weighing up its true identity, the bird got hold of a strong wind current that carried it at least 20 m above me in a fraction of a second. The underbelly was streaked while the wings had darker wing margins.

Meanwhile, the bird spotted something in the grass and swooped down on it. At this juncture it went out of sight while I waited to get another glimpse of it. Within moments it returned with something in its bill and settled on a *Ficus* sp. jutting from the vertical rock face to my right, but at a lower level than me. While the bird dismembered its booty, I crept up to almost 15 m from it. The head was pale and the conspicuous moustachial stripe of the common kestrel was not visible. The bird was holding on to a grasshopper with its claws. The claws lacked the dark tinge of the common kestrel and by then I was convinced that it was a female of the lesser kestrel *Falco naumanni*.

According to Ali and Ripley (1987), *Falco naumanni* is more patchily distributed than its larger cousin, *F. tinnunculus* and is an irregular passage migrant to East Africa. A few stragglers are known to remain behind and have been sighted between November and April in Ambala, Delhi, Lucknow (U.P.), Dinapur (Bihar), Balasore (Orissa), Kolkata (Bengal), Dibrugarh, Naga hills and N.E. Cachar (Assam), Manipur, to as far south as Chennai (Coonoor-Nilgiris). Within Maharashtra, a flock of several hundred birds has been sighted in Sholapur, apart from a flock of a dozen birds in Ahmednagar in January. Apart from this, there have been unpublished records of the bird from Nasik (Raha, B. pers. comm., 1999). *F. naumanni* is also recorded from Sri Lanka (Hoffmann, 1996).

Though rare, it is widely distributed in India. The inadequate data on the bird could probably be attributed to its resemblance to *F. tinnunculus*. The females of the two species are difficult to differentiate in the field. Only a trained eye can distinguish between the two birds from their hovering styles — instead of the up and down wing strokes of the common, the lesser kestrel beats its wings forward and backward. This is apparently because the body of the lesser kestrel is raised 45° while that of the common is held parallel to the ground. The most important identification is the paler, almost colourless claws of *F. naumanni* compared to the black ones of *F. tinnunculus*. This is the first record of this RED DATA BOOK species from Matheran and therefore worth mentioning.

November 25, 2000

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15. UNUSUAL FEEDING ASSOCIATION BETWEEN SIBERIAN CRANE *GRUS LEUCOGERANUS* AND WILD BOAR *SUS SCROFA* IN KEOLADEO NATIONAL PARK, BHARATPUR, RAJASTHAN

Siberian cranes *Grus leucogeranus* are wetland-dependant birds and unlike other cranes that often forage in dry upland areas near wetlands, they usually forage in ankle deep shallows (Sauey 1985). Three Siberian cranes were observed feeding in dried up areas of wetland in the Keoladeo National Park, Bharatpur, India. The cranes were in areas where the soil appeared ploughed and were observed picking up tufts of grass and putting them aside, and then picking up small items of food. After the cranes had moved away from the foraging sites, we noticed that the area had wet soil and was dug up by boars *Sus scrofa*, as was evident from the hoof marks and droppings of wild boars. All the grass was uprooted; tufts of roots and partly eaten insect larvae were lying all over. A bunch of larvae were wriggling under the tufts of grasses, which were lying all over the dug up areas.

Wild boars are known to feed on roots of grasses and sedges, and also on insects (Prater 1971). They had probably uprooted the grasses to get to these larvae. The cranes took advantage of the ploughing by the wild boars, as they themselves would have found it difficult to uproot the grasses in the dried up area where the soil had hardened after drying. The insect larvae were very small and individually not of much food value to cranes, but since they were available in abundance, the cranes may have found it profitable to feed on the larvae, which are not on their regular diet. Only the captive bred released birds, which were a part of an experiment to augment the wild population of Siberian cranes, were observed feeding on larvae. It was probably behaviour learnt from sarus cranes, as the Siberian cranes were associated with them more than with the wild Siberian cranes. The captive released birds would often venture out with the sarus cranes to forage in the dry areas. The Siberian cranes are known to feed largely on vegetable matter and occasionally on aquatic insects in their wintering grounds (Ali and Ripley 1983, Vijayan 1991).

Birds are known to benefit from feeding associations with other animals. Egrets *Egretta* spp., drongos *Dicrurus* spp., starlings *Sturnus* spp., mynas *Acridotheres* spp., and many other species follow grazing animals and pick up insects disturbed by the movement of these animals in the grass (Ali and Ripley 1983). However, we have not come across any reports of Siberian cranes, which are largely wetlands birds, getting direct benefit from the action of a terrestrial animal like the wild boar.

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16. COMMON COOT *FULICA ATRA* FROM KYONGNOSLA IN EAST SIKKIM

In early March 2000, there were reports of migrating water birds in groups of 50+ from the Kyongnosla area of east Sikkim (*c.* 3000 m). On March 15, 2000 one bird that had fallen from the sky from its group of *c.* 100 birds was caught and taken to a nearby settlement. Mr. Bishnu Sharma, Supervisor, Kyongnosla Alpine Sanctuary, immediately retrieved it and brought it to my office at Deorali, Gangtok the next day in a cardboard carton. The bird was an adult common coot *Fulica atra*. It was alert and active, stabbing at my hand with its bill, and it drank water copiously. It seemed unhurt and had no external injuries. As I had no apparatus to ring or measure it, or take photographs, I took it to my residence at the Forest Colony, Baluakhani, Gangtok (1,800 m) that evening, where it escaped. For over an hour it wandered in the garden before fluttering down to the road and going into the forest scrub further down. I watched for it till dark and could not find it the next morning.

The common coot, which has a wide distribution range over the Indian subcontinent, has not been recorded from Sikkim so far, though the area is a well known traditional flyway for water birds on return migration northwards in spring (Ali and Ripley 1983; Ali 1962) probably due to paucity of field surveys. This could therefore be considered a new record for Sikkim.

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17. SIGHTING OF THE LESSER FLORICAN *SYPHEOTIDES INDICA* IN GIR INTERPRETATION ZONE, DEVALIYA, GIR SANCTUARY

On June 27, 2000, I had gone to the Gir Interpretation Zone (GIZ), Devaliya, specially developed for tourism in the Gir Sanctuary. I had gone to check the health of the lions. The GIZ has a fenced area of 412 ha, with *c.* 100 ha of Savannah grassland. During the visit, Sardulbhai, one of my staff, informed me that an unknown bird similar to a small peahen had been spotted near the lions' feeding cage. On reaching the spot, I saw a domestic hen-sized bird with a crest on its head, at some distance. When we approached, the bird ran into a patch of tall grass and hid there in silence. To my great jubilation, I confirmed it as a male lesser florican (*Sypheotides indica*) through my binoculars and immediately took some photographs. It is for the first time that a lesser florican has been photographed in the Gir Protected Area. The same species was reported from the Gir Protected Area (and the sighting confirmed) during May and June, 1982. According to Sankaran *et al.* (1992) the lesser florican sometimes visits Babara Vidi grassland, Maliya taluka, Junagadh district, an ideal habitat for lesser florican. Our field staff and researchers have observed florican in this area several times.

From June 27 to July 10, I visited GIZ, Devaliya regularly, twice a day, morning and evening. The florican was mostly seen in the grasslands. I saw it display twice. To ascertain the presence of other lesser florican (especially female) in GIZ, I used a group of trackers, but sighted only the same male. After July 10, 2000, the bird left the GIZ, Devaliya.

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18. GREY-HEADED LAPWINGS *VANELLUS CINEREUS* SEEN AROUND MACHILIPATNAM, KRISHNA DISTRICT, ANDHRA PRADESH, INDIA

On February 17, 2001, at around 0645 hrs, I was watching waders of several species, along with other birds, on a largely flooded field, 1-2 km northwards of Chilakalapudi, Machilipatnam. Amongst the waders, which included several wood sandpipers, little ringed plovers, Pacific golden-plovers and a few little stints, were twelve larger birds. An initial look was enough to place them with lapwings (*Vanellus*) and the birds looked superficially similar to pictures of white-tailed lapwing, which I had seen.

Their posture was upright, with a small to medium sized, smooth round head with no crest. Size was similar to red-wattled lapwing (*Vanellus indicus*) of which there were three in a nearby field. The head and neck were a uniform pale grey colour with no supercilium or eye-stripe. The bill was bright yellow and no wattles could be seen on the face. A wide (1-2 cm) black breast band separated the grey of the neck from the belly, which was white. Legs were bright yellow, the same colour as the bill. The wings, which were seen when one of the birds flew a short distance, showed a very distinctive 'tri-coloured' pattern, with black primaries, white secondaries and brownish coverts, in three, straight edged blocks of colour.

The birds were watched for 30-45 minutes through a Bushnell Spacemaster Telescope with a 22x wide-angle lens and 8 x 32 Leica binoculars at a distance of perhaps 50-100 m (some of the birds were further away). Light conditions were good, with the early morning sun coming from just behind my right shoulder.

After consulting BIRDS OF THE INDIAN SUBCONTINENT by Grimmett *et al.* (1998), I was confident enough to identify the birds as grey-headed lapwings (*Vanellus cinereus*), which according to that book had not been recorded in Andhra Pradesh before.

On Friday February 23, at a different site, just east of Machilipatnam, 5 more grey-headed lapwings were seen, in groups of 2 and 3 in paddy fields on either side of a small road going down to the sea.

With the exception of the wing pattern (the birds did not fly) all the same features were observed, and in addition the black tip to the yellow bill was noted.

Six grey-headed lapwings were seen again just north of Chilakalapudi, Machilipatnam on March 13, 2001 and one on April 3, 2001.

March 24, 2001

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19. THE GREY-HEADED LAPWING IN TAMIL NADU - A REJOINDER

In his note on the grey-headed lapwing *Vanellus cinereus* (Blyth), [*JBNHS 97(2)*: 277], Gopi Sundar writes that in peninsular India, this species has only been recorded in Bangalore in 1987 prior to his sighting in Kaliveli Tank near Pondicherry in 1997. He further writes, "Perennou and Santharam have conducted detailed ornithological surveys in this region and have not come across this species."

I would like to point out that this is not true. Gopi Sundar has only referred to two of our publications and hence overlooked my note published in *Blackbuck 3*: 25-27 (1987). In this note, I had recorded the sighting of the grey-headed lapwing in Madras city (now Chennai) on January 11, 1987. The bird was spotted on a mud flat of the Adyar Estuary from the Theosophical Society estates. T.R. Shankar Raman had spotted it and all the nine bird watchers present on that occasion had a good look at the bird, which was a juvenile. The lapwing was not seen on subsequent visits. This record also finds a mention in the BIRDS OF THE INDIAN SUBCONTINENT (Grimmett *et. al.*, 1998 Oxford).

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20. A SIGHT RECORD OF BUFF-BREASTED SANDPIPER *TRYNGITES SUBRUFICOLLIS* IN GOA

At about 1225 hrs on November 18, 2000, while birdwatching with a Sunbird tour group in recently irrigated paddy fields at Santa Cruz, Tiswadi taluka, Goa, Rick Heil found a buff-breasted sandpiper *Tryngites subruficollis*. The bird performed superbly and was watched, by RH and five other observers including Paul I. Holt, David Hemmingway and Mark Newsome, uninterrupted for about 50 min and at ranges down to *c.* 75 m. We used a variety of binoculars and telescopes, some of the latter with eyepieces of up to 60x magnification. RH and PIH both had extensive experience of the species and all observers were completely confident of RH's initial identification. RH, PIH and MN took field notes and PIH did a hurried sketch (copies of these are held by PIH). Unfortunately, the bird, a juvenile showing no signs of moult to first-winter plumage, could not be located when other observers searched for it later the same afternoon.

Throughout the observation we were aware that, although the buff-breasted sandpiper is a very distinctive shorebird, it has, on occasion, been confused with the ruff *Philomachus pugnax* (several of which were present nearby) and with the extralimital Baird's sandpiper *Calidris bairdii*.

Description: The following description is a synthesis of notes taken by PIH, RH and MN.

Structure: A medium sized wader, fractionally smaller than the accompanying wood sandpipers *Tringa glareola* and proportionately slightly larger-headed and with a shorter and thicker neck than that species. The bird's head nevertheless appeared relatively small and its size, in combination with its plumage pattern and shape (in particular its steep forehead, flat crown and angular nape), created a soft, open-faced and almost dove-like impression. The bird's body also appeared slimmer, sleeker and more attenuated at the rear than those of the wood sandpipers.

The folded wings extended beyond the tip of the tail by a distance approximately equal to half the length of the bill, while two, and just possibly three, primary tips were visible beyond the longest, lanceolate and remarkably wispy tertial.

The bill, proportionately shorter than that of the wood sandpiper, was approximately equal to the length of the head. It was very straight, the lower mandible having an almost imperceptible arch along its lower edge, and tapered to a rather fine tip. The legs were similarly proportioned to those of the wood sandpiper.

Plumage: The whole face, front and sides of the neck and virtually the entire underparts were a remarkably uniform fawn-, or cinnamon-buff colour while the feathers of the upperparts were dark centred and neatly scalloped.

Head: A rather large, dark eye was very conspicuous on an otherwise plain, 'open' face. The ear-coverts were slightly duskier, setting off paler buff supercilia and there was a pale buff, broken eye-ring, more noticeable above the eye. The forehead was unmarked, though the crown, nape and hind-neck to mantle were marked with fine blackish streaks.

The upperparts were attractively patterned. Dark, almost blackish centres to the mantle, scapulars, wing coverts and tertials contrasted crisply with their broad buff or whitish-buff fringes. Compared to the rest of the upperparts, the centres to the wing coverts were paler, the fringes broader and more diffusely demarcated. The resulting pale wing panel contrasted quite well with the lower scapulars. The wing coverts also exhibited the anchor-shaped internal markings that are typical of juvenile buff-breasted sandpipers (A narrow blackish shaft being connected to a broader blackish sub-terminal crescent that traced the feather's shape). A similar pattern was also discernible in some of the lower scapulars. There were no signs of any moult, all of the upper-part feather tracts appeared rather fresh and were arranged in neat, linear rows. Individual feathers, particularly the larger wing coverts and rear lower scapulars, were easily identified and counted.

Wings: Although the bird was seen only very briefly in flight, it opened its wings, to stretch or to preen on a couple of occasions, and we were then able to discern some details of the wing pattern. The flight feathers were dark and contrasted well with the paler inner wing-coverts. A narrow, very indistinct, or even obscure (RH), pale-buff wing-bar was just apparent across the tips of the greater coverts. The under-wing coverts appeared clean white, contrasting with the underside of the flight feathers and especially with a relatively conspicuous blackish comma, or crescent, formed by the primary under-wing coverts.

Underparts: The chin was fractionally, but perceptibly, paler than both the face and the fore neck, and while the fawn-buff neck, breast and belly were concolorous the remainder of the underparts gradually faded paler and whiter from the rear belly through the vent to the undertail coverts. Isolated patches of bold, blackish flecking or spotting extended to either side of the breast.

Bare parts: The bill appeared dark and there was possibly a very small, slightly paler area at the extreme base of the lower mandible. The legs were a uniform olive-yellow, the colour of English mustard, and had a slightly more orange hue than those of all the accompanying wood sandpipers.

Behaviour: During our observation the bird fed busily. It was almost constantly on the move, walking around the paddies with a distinctive head-bobbing, almost dove-like motion and high stepping, tripping gait. No interaction was noted between it and any of its equally busily feeding companions. As is typical of the species, the bird remained silent.

Status: Buff-breasted sandpiper is almost exclusively Nearctic in its distribution. It breeds across the Arctic belt of North America from Alaska to western Canada, as well as on Wrangel Island and perhaps the Chukotskiy peninsula, Siberia (Cramp and Simmons 1983). It winters in northeast South America. Brazil (1991) listed 12 records from Japan and, although the species has not been recorded anywhere in southeast Asia (Robson 2000), there is at least one report from the east coast of Taiwan (MacKinnon and Phillipps 2000), and at least eight sightings in Australia (Pringle 1987). There are four previous records from the Indian subcontinent. Three of these reports are from the east coast of Sri Lanka - a specimen collected by T.S.U. De Zylva at Kalametiya near Hambantota on the March 5, 1960, and two subsequent sight records, one near Trincomalee in November 1974 and the other at the Bundala Sanctuary on the January 19-23, 1985 (*CBCN* 1960: 14, *CBCN* 1974: 41, *CBCN* 1985: 2, Hoffman 1991 and Lamfuss 1998). The only previous record from India was of a bird seen by Per Undeland at Harike Bird Sanctuary, Punjab on the May 18, 1995 (Robson 1996). Perhaps even more surprisingly, there are three recently accepted records (12.iii.1981, 31.x. – 14.xi.1997 and 13-19.xi.1999) from the Seychelles (David Fisher pers. comm. and Adrian Skerrett *in litt.* to PIH).

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Krys Kazmierczak kindly provided information on the previous subcontinent records, supplied several references, contact addresses and reviewed a draft of this note. Guenter Lamfuss responded speedily to our requests for further information on the Sri Lankan records and both David Fisher and Adrian Skerrett provided information concerning the species' status in the Seychelles.

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21. GROUP FISHING OF HOUSE CROWS (*CORVUS SPLENDENS*) WITH RIVER TERNS (*STERNA AURANTIA*)

(*With one plate*)

On July 6, 2000, during a visit to Bigwan, Indapur taluka, Pune district, Maharashtra State for bird watching, I noticed a flock of about 40 river terns (*Sterna aurantia*) and 10 house crows (*Corvus splendens*), flying together at one spot, in the backwaters of Ujani Dam. As I approached closer, I saw fishermen emptying their catch from the nets.

The house crows and river terns were diving for the dead fish, which had fallen from the fishing nets, and were floating on the water. The crows had mastered the technique of hovering and accurately picking up the fish, just like the river tern.

The house crow is not a water bird; whether this was a natural instinct or it had mastered the technique while observing the river terns is a big question. Crows are known to be territorial and aggressive, but in this case they neither harmed nor quarreled with the terns.

Another observation worth noting was that while the river tern picked up and swallowed the fish in flight the crow would pick up a fish, fly to the shore to eat it, and then fly back to catch another one.

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22. TERNS OF THE VENGURLA ROCKS, A REVIEW AND UPDATE

The breeding colony of maritime terns on the Vengurla Rocks is arguably the Indian subcontinent's most important one, if not for the sheer quantity of nesting birds then for the number of constituent species. Though it has been known for at least 125 years that a ternery exists on Burnt Island, one of the islets forming the Vengurla Rocks, all knowledge about it rested on local lore, second-hand accounts and circumstantial proof. No ornithologist had ever seen terns there before 1981.

The Vengurla Rocks are a tiny archipelago of rock outcrops situated 16.5 km off the South Konkan coast from a point about halfway between Vengurla and Malwan (Sindhudurg district, Maharashtra State, India), situated at 15° 43' 24" N and 73° 27' 42" E. The four largest ones form a group of precipitous rocky islets at a distance of several hundred metres from each other. Among them, the smallest and westernmost is crowned by the ruins of the old lighthouse. This was replaced around 1935 by a more modern one on the largest of the rocks, manned by a crew of eight that resides on it throughout the year. Burnt Island, the second largest of the islets, lies closest to the mainland. It is about 300 m long, 100 m wide and 30-50 m high, and sparsely covered by coarse grass and a few stunted bushes. The islet remains free from human interference and A.O. Hume's (1876) detailed description is as accurate and valid today as it was 125 years ago.

The group of islets as a whole presents a forbidding aspect, access is limited to the fair season, October to May, and landing is risky even at the best of times. In January 1998, permission given to me to stay at the Inspection Quarters of

Naik, Sattyasheel N.: *Corvus splendens* & *Sterna aurantia* PLATE 1

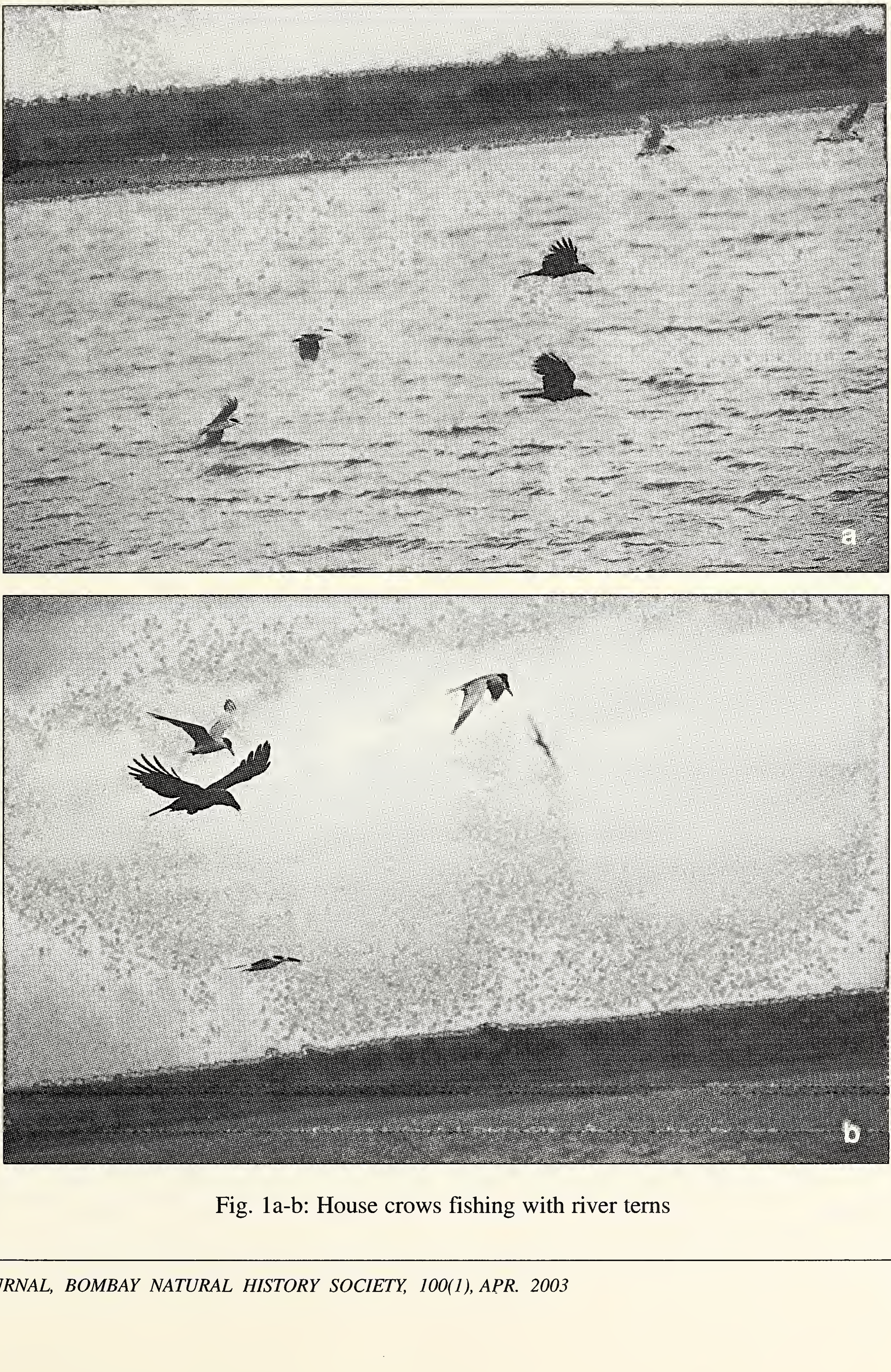

Fig. 1a-b: House crows fishing with river terns

the lighthouse island was revoked by the Directorate of Lighthouses and Lightships, after a crewman was killed when trying to alight from the departmental boat on to the rock. During the southwest monsoon, the time when the terns breed, the Vengurla Rocks are totally inaccessible, and the lighthouse crew is cut off from the world between May 31, when a country-craft under contract brings the last supplies, and early September, when communications are resumed.

Antecedents

It was the breeding colony of edible-nest swiftlets on Burnt Island that caught the interest of ornithologists in the second half of the 19th century. The taxonomic status of these enigmatic swiftlets was heatedly discussed then, and the ornithologists' demand for bird specimens must have been as great and urgent as the Chinese gourmet's for their soup-providing nests. All we came to know about the equally enigmatic ternery was an incidental spin-off of these studies.

A.O. Hume (1876), in February 1875, visited three of the islets and spent several hours on Burnt Island on his way to the Laccadives (now Lakshadweep). He did not see any terns, but collected desiccated remains of terns and eggs. G.W. Vidal (1880), solely interested in swiftlet specimens, sent his 'shikaree' on collecting trips to the Vengurla Rocks in April 1878, December 1879 and February and April 1880. Some years later, J. Davidson apparently got a number of tern eggs collected by the crew of the old lighthouse (*vide* Whistler in Abdulali 1939).

The issue of the specific status of the Indian edible-nest swiftlet *Collocalia unicolor* (Jerdon) having been settled by then, nobody seems to have taken interest in the Vengurla Rocks until Humayun Abdulali took up the challenge over 40 years later. He turned out to be the most enterprising of all the visitors, managing to land, and even stay overnight, on Burnt Island in February 1938 and 1941 (Abdulali 1939, 1941). Forty years later, in May 1981, he undertook another collecting trip to Burnt Island, this time of only a couple of hours duration. It yielded, besides various desiccated remains of adult birds, chicks and eggs, the first sight-record of live terns: a group of some 50 birds, identified as *Sterna anaethetus* and a few *S. fuscata*, circling half a mile from the Rocks (Abdulali 1983).

A critical appraisal of the old breeding records

By 1982, the following six tern species were established and listed in the HANDBOOK and SYNOPSIS - as breeding on the Vengurla Rocks. One of these, the sooty tern *Sterna fuscata*, should be omitted.

Roseate tern *Sterna dougallii* Montagu (Syn. No. 466): A number of eggs collected on Burnt Island by the lighthouse staff sometime during the last decade of the 19th century were ascribed by J. Davidson to this species 'without keeping notes on how he arrived at this identification' (Whistler in Abdulali 1939). This probably had prompted E.H. Aitken to state in his COMMON BIRDS OF BOMBAY (*c.* 1900): 'The Roseate Terns breed in the Vingurla Rocks (*sic*) during the monsoon.'

Addled eggs and desiccated bird-remains, collected by Abdulali in 1938 and 1941, were examined by Hugh Whistler at the British Museum, London, and Sálim Ali at the Bombay Natural History Society and identified as belonging to this species (Abdulali 1939, 1941).

White-cheeked tern *S. repressa* Hartert (Syn. No. 467): Out of Abdulali's 1938 and 1941 material, Ticehurst examined the mummy of a juvenile tern, and Whistler and Sálim Ali several addled eggs that they ascribed to this species (Abdulali 1939, 1941). Apparently, there were no signs of this tern having bred at the time of Abdulali's 1981 visit to Burnt Island.

Bridled tern *S. anaethetus* Scopoli (Syn. No. 471): Hume (1876) found, in February 1875, on Burnt Island "innumerable addled, broken and more or less decayed tern's eggs, while all about in similar situations, mummies, desiccated corpses of young birds of all ages and a few old *S. anaethetus* lay scattered leaving no possibility of doubt as to the species which chiefly breeds there." The bird and egg remains he collected were identified at the British Museum, London.

Sooty tern *S. fuscata* Linn. (Syn. No. 474): Sálim Ali, when examining the material collected by Abdulali in February 1938, had noted: "... Two brown wings, however, measure 270 and 294 mm, and apparently belong to the sooty tern (*S. fuscata*). This is a new record for Vengurla; the nearest hitherto known breeding place is in the Laccadives. A beak measuring 40 mm may support this identification." (*vide* Sálim Ali in Abdulali 1939).

This record of a mere 'occurrence' of this tern has found its way as a 'breeding record' into works like Ali and Ripley (1983), Harrison (1985), Grimmett *et al.* (1998) and Kazmierczak (2000). I feel that Sálim Ali had jumped here to an inadmissible conclusion: The presence of a pair of wings and a beak on Burnt Island hardly constitutes proof of the bird having bred there. Ripley (1982) did not follow Sálim Ali's reasoning and omitted this 'breeding record' from his SYNOPSIS.

Little tern *S. albifrons* Pallas (Syn. No. 475): Desiccated remains of mostly downy chicks with emerging feathers, collected by Abdulali in May 1981, were identified by Dr. Jon Fjeldså at the Zoological Museum of the University of Copenhagen, Denmark, as being of this species (Abdulali 1983).

Though a modicum of doubt must adhere to a specific identification of small chicks without any supporting evidence, especially if the specimens are of the smallest species out of a mixed breeding colony that abounds in chicks of species only slightly larger than the bird in question, Dr. Jon Fjeldså remains confident of his identification (in litt. 31.i.2001).

Large crested tern *S. bergii* Lichtenstein (Syn. No. 478): Addled eggs and mummified remains of a juvenile bird, collected by Abdulali in February 1938 and 1941, were examined by Whistler at the BMNH, London, and Ticehurst and Sálim Ali at the BNHS, Bombay, and ascribed to this species.

Recent visits

In May 1988, Stig T. Madsen, a Danish bird watcher interested mainly in seabirds, undertook an exploratory cruise through the group of islets on a fishing trawler chartered at Vengurla (Madsen 1988). His report of having seen *c.* 20 each of *S. anaethetus*, *S. repressa* and *S. bergii* and 300-500 unidentified terns prompted me to accompany him on a three day stay at the inspection quarters of the Lighthouse Is., at the end of March 1989. To reach the Rocks we hired a motorized and outrigger-fitted dugout-canoe at Kochra, a fishing village at the mouth of a narrow creek between Vengurla and Malwan, at the closest distance to the Vengurla Rocks.

By the same mode of transport, I visited the Lighthouse Is., again for three days each time, in mid-May and mid-October 1989. A Zeiss 30x60 refractor was used to observe tern activity on close-by Burnt Is. and in the entire 'archipelago'. A further trip, rounding Burnt Island for a couple of hours and spending the night on the canoe in its vicinity, was made in mid-September. In mid-December 1989, I landed on Burnt Island, but suffering from a bout of vertigo, was not able to collect more than a couple of tern mummies.

These visits spread more or less randomly throughout the fair season, served to determine or, at least, to narrow down the time when the terns appeared on and left from their breeding ground.

After a hiatus of nearly 8 years, a new series of visits was undertaken in an attempt to get a glimpse of the breeding terns themselves.

Using a hired, diesel-powered, open fibreglass boat out of Kochra, I circled Burnt Is. on June 5 and 9, and September 30, 1997, accompanied by Gordon Frost and Nick Manville on two of these outings. After an uneventful visit on April 30, 1998, an unexpected lull in the southwest monsoon allowed me to see the breeding colony at its apparent peak on August 16, 1998. During this crucial visit, an immense 'cloud' of well over 15,000 terns could be observed on the precipitous leeward (towards the mainland) side of Burnt Island. In addition to that, a conservatively estimated 10,000 terns were spread over the less steep seaward side, but the almost impenetrable spray created by thunderous breakers and the heaving and tossing of the small boat made closer observations and a species-wise break-up impossible.

These 12 visits, spread over the years 1988-89 and 1997-98, covered all seasons and all months except January, February, July and November.

Breeding terns

Roseate tern *Sterna dougallii* Montagu (Syn. No. 466):

March 25, 1989: Flocks of up to *c.* 700 smallish white terns, too distant for identification, visited the vicinity of the Vengurla Rocks.

June 5, 1997: The first positive sighting of roseate terns on Burnt Island, just two days before the regular and 10 days before the actual onset of the southwest monsoon. Well over 800 birds in full breeding plumage were sitting openly on rock-ledges, not more than 10 m above the waterline or flying close to the islet. Though almost all these terns seemed to be paired off, there was no visible breeding activity as such.

August 16, 1998: A conservatively estimated number of 10,000 adult birds milled around the islet in a veritable feeding frenzy. They kept coming in, mainly from the seaward side, with small fish in their bills, diving into rock fissures and crannies and wider tussocks of the lush coarse grass, all located on the lower half of the islet obviously feeding the downy chicks and youngsters hidden there, and taking off immediately to haul in more. Very few fully-fledged juveniles were perched openly on rock-ledges, while many adults were apparently still incubating clutches of eggs or brooding freshly hatched chicks.

September 9, 1997: Hectic feeding of concealed youngsters by over 4,000 adult birds continued. Only a dozen or so fully-fledged juveniles were visible. The rosy tinge of the breeding plumage had already faded in about half of the adults.

September 30, 1997: Only just over 80 birds, including 5 juveniles were present. Feeding activity had ceased. The adults breeding plumage had almost completely faded.

October 14, 1989: All roseate terns had left Burnt Island.

Bridled tern *S. anaethetus* Scopoli (Syn. No. 471):

May 10, 1981: Up to 50 birds were present in the group of islets.

May 13, 1989: The activity of the over 400 birds present was loosely centered on Burnt Island. Roughly one half of the birds were already paired off, standing for long stretches of time on rock-ledges and under overhanging rocks of the seaward side. The other half were wheeling in circles over the islet and chasing each other in a sort of aerial nuptial display. At dusk, the terns dispersed; no roosting on any of the islets was observed. During the night, no calls were heard from the vicinity.

June 5, 1997: More than 400 bridled terns had occupied crags and fissures on the lower half of the seaward side, apparently incubating.

August 16, 1998: Well over 3,000 adult birds were present, frenziedly feeding chicks and youngsters that were hidden from view. Very few fully-fledged juveniles were visible.

September 9, 1997: Over 300 adult birds were perched on the leeward side of Burnt Island; no juveniles were visible; all feeding activity had stopped.

September 17, 1989: Over 200 terns were either wheeling around the islet or surface feeding in the vicinity. Going by their calls, they appeared to keep up their activity throughout the night. Between the Vengurla Rocks and the mainland, *c.* 60 birds per hour were continually passing on their autumnal southward mass migration, presumably from their breeding grounds on the southern shores of the Red Sea and the Persian Gulf.

September 30, 1997: All bridled terns had left.

Large crested tern *S. bergii* Lichtenstein (Syn. No. 478):

This tern occurs along the South Konkan coast throughout the year in small groups and loose flocks of up to 800 (Lainer 1999a). Around the Vengurla Rocks, small numbers (up to 25 birds) were commonly seen during the dry season.

June 5, 1997: Over 1,000 birds were perched on rock-ledges, crags and pinnacles on the highest parts of Burnt Island. No breeding activity was apparent.

August 16, 1998: More than 2,000 adult birds were feeding chicks and youngsters that were hidden from view. Very few ready-to-fly immatures were visible.

September 9, 1997: Only *c.* 200 adult terns occupied the top of the islet. Feeding activity had ceased; no juvenile birds were to be seen.

September 30, 1997: Over 300 birds were spread all over the group of islets and tide-washed rock-pinnacles in the vicinity.

October 14, 1989: Not a single tern present on Burnt Island.

Non-breeding terns

Caspian tern *Hydroprogne caspia* (Pallas) (Syn. No. 462):

Status: On passage in the vicinity of the Vengurla Rocks.

On March 25, 1989 over 10 birds were seen moving in the 'archipelago' and two between the Vengurla Rocks and the mainland on September 30, 1997.

Common tern *Sterna hirundo* Linn. (Syn. No. 465):

Status: Uncertain.

A desiccated head of a tern, collected by me on Burnt Island on December 15, 1989, was identified by S.A. Hussain at the BNHS, Mumbai, as belonging to this species. Unfortunately, the specimen has not been preserved in the collection.

White-cheeked Tern *S. repressa Hartert* (Syn. No. 467):

Status: Formerly a breeding summer visitor, now probably only on passage during the annual southward mass-migration from July to September and the less spectacular return flight from March to May.

Madsen (1988) reported the sighting of *c.* 20 birds on the seaward side of the group of islets, on March 21, 1989. This species may have been present in the roving flocks of unidentifiable small white terns observed in May 1989.

Sooty tern *S. fuscata* Linn. (Syn. No. 474):

Status: Rare or occasional visitor.

Abdulali (1983) reported the sighting of a few of these terns among a flock of *c.* 50 bridled terns circling half a mile from the Rocks. On April 30, 1998 I saw 8 birds in the vicinity and identified them tentatively as of this species.

Sooty terns are uncommon, but far from rare, visitors off the South Konkan coast especially in August-September during the annual mass-migration of white-cheeked and brown-winged (now bridled tern) terns (Lainer 1999a).

Lesser crested tern *S. bengalensis* Lesson (Syn. No. 479):

Status: A roving visitor, regularly on passage.

Over 50 birds, in small groups, were observed on northward migration on March 26, 1989. Southward passage in twos and threes was recorded in September and October 1989 and 1997. Their flight path invariably lies between the Vengurla Rocks and the mainland.

Sandwich Tern *S. sandvicensis* Latham (Syn. No. 480):

Status: Unusual, on passage.

At least 3 birds were observed in the vicinity on March 25, 1989. Groups of 20-25 birds kept passing in straight and purposeful northward flight, about a kilometre from the Rocks on May 13, 1989. Sandwich terns are common visitors all along the South Konkan coast throughout the year (Lainer 1990).

Brown noddy *Anous stolidus* (Linn.) (Syn. No. 481):

Status: Stray or rare visitor.

On September 9, 1997, 18 birds were observed perched on rock-ledges and stunted bushes on the leeward side of Burnt Island. Three weeks later, only a single brown noddy was found there (Lainer 1999b).

Comments

Of the six tern species that were thought to breed on Burnt Island (*S. dougallii, S. repressa, S. anaethetus, S. fuscata S. albifrons* and *S. bergii*) the sooty tern should be omitted.

A minimum of 10,000 *S. dougallii*, 3,000 *S. anaethetus* and 2,000 *S. bergii* bred during the southwest monsoon of 1998 on the leeward side of Burnt Island. These numbers would increase by 30% if one assumes that the over 10,000 terns on the seaward side were of an identical or at least similar species break-up.

Egg-laying and incubation started after the traditional, regular onset of the southwest monsoon in the area (June 5-7), probably after the actual onset, if that should be at a later date.

The simultaneous presence of fully-fledged juveniles and adult birds still incubating in mid-August suggests that second broods are taken up, possibly after the loss of the first.

The surprisingly small number of fully-fledged juveniles present towards the end of the breeding season suggests that youngsters leave the colony as soon as they are able to fly or soon after. This ties in well with the annual southward mass migration of *S. anaethetus* and *S. repressa* off the coast of Goa, where I noticed that the earlier part of the migratory stream (starting usually at the end of August) is a trickle of mainly juvenile birds, while the adults follow in a solid rush from mid-September onwards.

The mixed ternery shows a strictly stratified structure: *S. dougallii*, the smallest of the constituent species, occupies the lowest rock-strata, up to 10-15 m above the high-water line. The medium-sized *S. anaethetus*, though mingling with *S. dougallii* in the upper reaches of their zone, breed at an intermediate height while the large *S. bergii* adhere to the uppermost parts of the islet.

Records of other bird species

Apart from terns, the following 26 bird species were recorded on the Vengurla Rocks or in the close vicinity:

1. **Indian pond-heron *Ardeola grayii* (Sykes)** (Syn. No. 42): A single bird on Burnt Island in December 1989.
2. **Western reef-egret *Egretta gularis* (Bosc)** (Syn. No. 50): Single birds were seen in March and November on Burnt Island.
3. **Brahminy kite *Haliastur indus* (Boddaert)** (Syn. No.135): Singles among the islets in March and May.
4. **White-bellied sea-eagle *Haliaeetus leucogaster* (Gmelin)** (Syn. No.173): Pairs and singles were observed in February, March, May, October and December.
5. **Western marsh-harrier *Circus aeruginosus* (Linn.)** (Syn. No. 193): Two immature birds over Burnt Island on September 30, 1997.
6. **Osprey *Pandion haliaetus* (Linn.)** (Syn. No. 203): One to three birds were seen in the archipelago in February, March, May (!), September, October and December.
7. **Peregrine falcon *Falco peregrinus***

Tunstall (Syn. No. 209): Singles were hunting among the islets in March, October and December.

8. **Common kestrel** ***Falco tinnunculus*** **Linn.** (Syn. No. 222): A pair was recorded in February 1875 by Hume (1876).

9. **Common Sandpiper** ***Tringa hypoleucos*** **Linn.** (Syn. No. 401): Several birds recorded in October and December.

10. **Ruddy turnstone** ***Arenaria interpres*** **(Linn.)** (Syn. No. 402): Up to 4 birds on rocks surrounding Burnt Island in May and August (!).

11. **Jaeger sp.** ***Stercorarius*** **sp.**: Two adult birds in non-breeding plumage among the islets on March 25, 1989.

12. **Heuglin's gull** ***Larus heuglini*** **Bree** (Syn. No. 450): Nine birds passing through the archipelago on northward migration on March 26, 1989.

13. **Brown-headed gull** ***Larus brunnicephalus*** **Jerdon** (Syn. No. 454): Hundreds among the islets in March and December 1989.

14. **Black-headed gull** ***Larus ridibundus*** **Linn.** (Syn. No. 455): Less numerous than the preceding species in December 1989.

15. **Blue rock pigeon** ***Columba livia*** **Gmelin** (Syn. No. 517): Breeding resident on Burnt Island. Present throughout the year except in July. Hume (1876) saw a few of these birds on Burnt Island in 1875, Abdulali (1983) estimated about 200 of what he deemed feral pigeons in 1981; I noted well over 500 of them on June 5, 1997.

16. **Oriental turtle-dove** ***Streptopelia orientalis*** **(Latham)** (Syn. No. 531): One coming in from the sea and alighting on the base of the lighthouse in October 1989; two birds on Lighthouse Is. in December 1989.

17. **Indian edible-nest swiftlet** ***Collocalia unicolor*** **(Jerdon)** (Syn. No. 685): Breeding resident on Burnt Island, absent during the southwest monsoon. The largest number I noted were "tens of thousands, a virtual cloud over Burnt Is." on March 25, 1989.

18. **House swift** ***Apus affinis*** **(J.E. Gray)** (Syn. No. 703): Up to 200 birds over the archipelago in March and December.

19. **Common hoopoe** ***Upupa epops*** **Linn.** (Syn. No. 765): A single on Lighthouse Is. on October 14, 1989.

20. **Greater short-toed lark** ***Calandrella brachydactyla*** **(Leisler)** (Syn. No. 886): A couple of flocks of *c*. 25 birds each passing over Lighthouse Is. on October 15, 1989.

21. **Black Drongo** ***Dicrurus macrocercus*** **Vieillot** (Syn. No. 963): Two birds commuting between Lighthouse Is. and Burnt Is. on October 14 and 15, 1989.

22. **House Crow** ***Corvus splendens*** **Vieillot** (Syn. No. 1049): Singles on the Lighthouse Is. in March and December.

23. **Black-headed cuckoo-shrike** ***Coracina melanoptera*** **(Ruppell)** (Syn. No. 1079): A juvenile bird perched all morning in the gantry of a crane on Lighthouse Is. on October 16, 1989.

24. **Asian brown flycatcher** ***Muscicapa dauurica*** **Pallas** (Syn. No. 1407): A single bird foraging on the rocky ground of the totally barren Lighthouse Is. on October 15, 1989.

25. **Blue rock-thrush** ***Monticola solitarius*** **(Linn.)** (Syn. No. 1726): Noted on all the islets of the group in February, March and October.

26. **Grey wagtail** ***Motacilla cinerea*** **Tunstall** (Syn. No. 1884): Two birds on Lighthouse Is. on October 15, 1989.

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23. RANGE EXTENSION OF ALEXANDRINE PARAKEET *PSITTACULA EUPATRIA* IN GUJARAT

In Gujarat State, the Alexandrine parakeet *Psittacula eupatria* is known to occur in Mahal (Dang), Waghai (Surat), Rajpipla (Narmada), and Gangasagar (Banaskantha) districts (Ali 1954). In recent publications, the species is reported only from the Rajpipla forest, but is uncommon (Monga and Naoroji 1983, Desai *et al.* 1993, Narve *et al.* 1997). Khacher (1996) and Grimmett *et al.* (1998) do not add new information about its distribution in Gujarat.

In Oct. 1992 and 1993, we had seen the species feeding on maize *Zea mays* cobs at Vatrak, Modasa and Himmatnagar of Sabarkantha district. After that, almost every year, a few pairs can be seen on a river bridge at Vatrak. We saw the bird first at Anand (Anand district), on Apr. 17, 1999 in the Institute of Rural Management campus. After that there were several records every month. At Nadiad (Kheda district), Shri Prathmesh Patel (pers. comm. in 1999) saw 3 wild birds hovering around his captive *P. eupatria* during Nov. 1999. At the Indian Petrochemicals Corporation Ltd. Township, Vadodara (Vadodara district), it was heard frequently over the last 3 years. We saw one bird on a banyan tree (*Ficus religiosa*) on Jul. 14, 1999 at Jambughoda Wildlife Sanctuary and several birds on Feb. 20 & 21, 2000 at Ratanmahal Wildlife Sanctuary (both in Panchmahal district). There is a recent record of its occurrence from Ahmedabad city (Ketan Tatu pers. comm. in 2000) and BMP saw one bird in flight on Nov. 6, 2000 at Kalupur Railway station, Ahmedabad. At Bhavnagar, four adult birds are regularly seen since 1998 (Indra Gadhavi pers. comm. in 2000).

The above records prove that the species has extended its distributional range in Gujarat State and also breeds in some parts of Kheda and Sabarkantha districts. Like elsewhere in India (Mehrotra and Bhatnagar 1979), it raids maize crops in Gujarat too. Our observation of a few pairs around holes on the river bridge indicate a search for unusual nesting structures by these birds,

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24. MIMICRY OF A CROW CHICK BY AN ASIAN KOEL *EUDYNAMYS SCOLOPACEA* AS A DEFENCE AGAINST ATTACK BY HOUSE CROWS *CORVUS SPLENDENS*

The Asian koel *Eudynamys scolopacea* is a common brood parasite of corvids, mynas and other species throughout India and much of southeast Asia. In India, this cuckoo's predominant host is the house crow *Corvus splendens* and to a lesser extent the jungle crow *C. macrorhynchos* (Lamba 1976). This author has observed that the high populations of house crows in towns and villages accounts for the large concentrations of Asian koels that may sometimes occur there. Despite the commonness of this brood parasitic relationship, the exact way in which Asian koel gains access to the hosts' nest for egg laying remains a point of controversy.

An interaction observed between an Asian koel and a group of house crows in the village of Anjuna, Goa on December 17, 1999, at a time when house crows were breeding in the area, may throw light on this question.

Observation

At dusk, about 1800 hrs, a group of five house crows were seen noisily chasing a female, or perhaps a juvenile, Asian koel. The latter alighted in the top of a coconut palm and was immediately surrounded by the house crows that were cawing loudly and aggressively. One crow moved within *c.* 30 cm of the Asian koel, and seemed about to launch a pecking attack. At that moment, the Asian koel responded to this threat by opening its mouth wide to reveal the bright red gape, which was held upwards, and emitting a call closely resembling that of a begging house crow chick.

This display by the Asian koel resulted in an instantaneous halt to the attack by the approaching crow, while the other four crows also became silent and passive. After about two minutes, during which time no further aggressive behaviour was displayed by the crows, the Asian koel slipped away into the semi-darkness of the coconut grove. The light was now failing rapidly and after a few minutes more of perching around abstractedly, the crows also flew off singly.

Discussion

House crows are well known to behave aggressively towards both sexes of the dimorphic Asian koel, particularly during the breeding season, chasing them on sight even far from nest, sometimes physically attacking them (Hume 1889; Lamba 1963) and even in rare cases killing them (Lamba 1976). The peak breeding season for house crows in southern India is April to May but some breeding, as in the present case, takes place in November and December (Lamba 1963).

Given this aggressive behaviour on the part of the hosts, there has been discussion and speculation over the years as to how the female Asian koel finds the opportunity to deposit her eggs in the vigilant house crow's nest. Dewar (1907) and Dharmakumarsinhji (1954) described several instances in which Asian koels appeared to take advantage of this aggressive response to facilitate access to the house crow's nest for the egg loaded female Asian koel. Dewar proposed a scenario in which the black male Asian koel lures the sitting house crow away from the nest, so that the cryptically marked brown-barred female Asian koel can slip in to deposit its egg. Although Lamba (1963) at one time accepted this hypothesis, by 1976, his own extensive studies had led him to believe that such observations were coincidental rather than a well-orchestrated strategy and that, in fact, it was simply a case of the female Asian koel taking any opportunity to get to the unoccupied nest. Furthermore, Eates (undated) described three instances where female Asian koels were seen in nests alongside incubating house crows, flapping and jockeying for position, and that calls resembling those of young house crows were heard. In each case, the Asian koel laid an egg and was not attacked by the resident crow. This suggests that the female Asian koel produced a call like a young house crow to appease the rightful occupant of the nest.

The instance described here, not only involved mimicry of a crow chick, but also of the chick's gape and begging behaviour. The Asian koel had a bright red gape, resembling that of a house crow chick. Goodwin (1986) also described the inside of the house crow chick's mouth as fleshy red and Lamba (1976) as blood red. Interpretation of the observation described here depends on whether the Asian koel in question was an adult or a juvenile. Stuart Butchart (pers. comm.) pointed out that fledgling Asian koels have a bright red gape, but that this probably becomes duller in adults, as is the case with other cuckoos. As no gape flange was visible, the bird would not have been a recent fledgling. However, older fledglings do indeed resemble females. If the Asian koel were a juvenile, it may have provoked a mixed response from the crows: mobbing whilst in flight, followed by tolerance once begging was initiated.

In any case, it seems likely from the various published descriptions mentioned above, that female Asian koels retain this fledgling-like behaviour and may resort to mimicry of house crow chicks to avoid physical attack when they have been cornered and are unable to escape. In the case of Eates' observations, perhaps the female koels were in the process of egg laying in an unoccupied nest when the house crow returned and, through mimicking a chick, the Asian koel was able to finish depositing an egg and depart without attack. The key to understanding this interaction is whether the gape colour of the adult female Asian koel is able to elicit the appropriate parental response in house crows. Clearly, such an ability would have enormous survival value, not only for the individual Asian koel, but also for the species as a whole.

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25. BUFFY FISH-OWL (*KETUPA KETUPU*) IN SUNDARBANS, BANGLADESH

(*With one plate*)

Three species of fish-owl are known from the Indian subcontinent: the brown fish-owl (*Ketupa zeylonensis*), the tawny fish-owl (*Ketupa flavipes*) and the buffy fish-owl (*Ketupa ketupu*). The last sightings of the buffy fish-owl from Assam were recorded by Stevens (1915) and Baker (1927). Stevens writes "Common in the forest streams which emerge into the Dibru" and mentions localities "Rungagora, 1902" and "Dejoo, North Lakhimpur, 1911". Baker says "I found it not very rare in the hills of South Assam and Coltart obtained one specimen in Dibrugarh". Further, "Coltart and I obtained eggs in the Khasia Hills and North Cachar".

The buffy fish-owl, also called the Malay fish-owl, is common in southeast Asia. According to Koenig *et al.* (1999) and del Hoyo *et al.* (1999), its present range of distribution covers Myanmar, Thailand, Vietnam, the Malaysian Peninsula and Indonesia (including Sumatra, Java, Borneo).

Fish-owls are not rare in the Sundarbans, and the huge mangrove forest in the lower delta of the Ganga, but are usually hard to identify when only seen in flight in poor light conditions. Some more recently published bird lists (Khan 1986; Hussain and Acharya 1994) mention brown fish-owl and tawny fish-owl, or only brown fish-owl, to occurring here.

It was only in November 2000, that we were able to photograph fish-owls in the southeastern Sundarbans of Bangladesh (Kotka Sanctuary – Plate 1) in early mornings and late afternoons. Analysing the photographs of three different individuals, all of them could be identified as buffy fish-owls.

Main characteristics of the buffy fish-owl:

— at 38-48 cm it is smaller than the brown fish-owl (56 cm) and tawny fish-owl (58-61 cm);
— lacking fine horizontal cross-barrings on underparts (typical for the brown fish-owl);
— colour above rich brown (against rich orange-rufous to tawny of the tawny fish-owl, and duller brown of the brown fish-owl);
— bare tarsi (against partly feathered tarsi of the tawny fish-owl);
— relatively short tail with few whitish bands (against longer, more narrowly barred tail of the tawny fish-owl);
— wings more broadly and buffish-white barred (against less broad orange-buff barrings of the tawny fish-owl).

This is, as far as known, the first record of the buffy fish-owl from Sundarbans and a rediscovery of the species in the Indian subcontinent (last record by Baker) after almost 80 years! It is perhaps not impossible that the buffy fish-owl was overlooked or mistaken for a tawny fish-owl, as Ali and Ripley (1969) along with their PICTORIAL GUIDE (1983), widely used in the past decades for identification of owls on the Indian subcontinent, does not mention the species. We became aware of the buffy fish-owl when consulting Grimmett *et al.* (1998).

The fauna of Sundarbans has, besides the buffy fish-owl, several other affinities with the Malaysian Region. Paynter (1970) mentioned laced woodpecker, blue-winged pitta, mangrove whistler and orange-bellied flowerpecker in this context (specimens collected in 1958 in the Sundarbans of Bangladesh). Other species from

Neumann-Denzau, Gertrud and Helmut Denzau: *Ketupa ketupu* PLATE 1

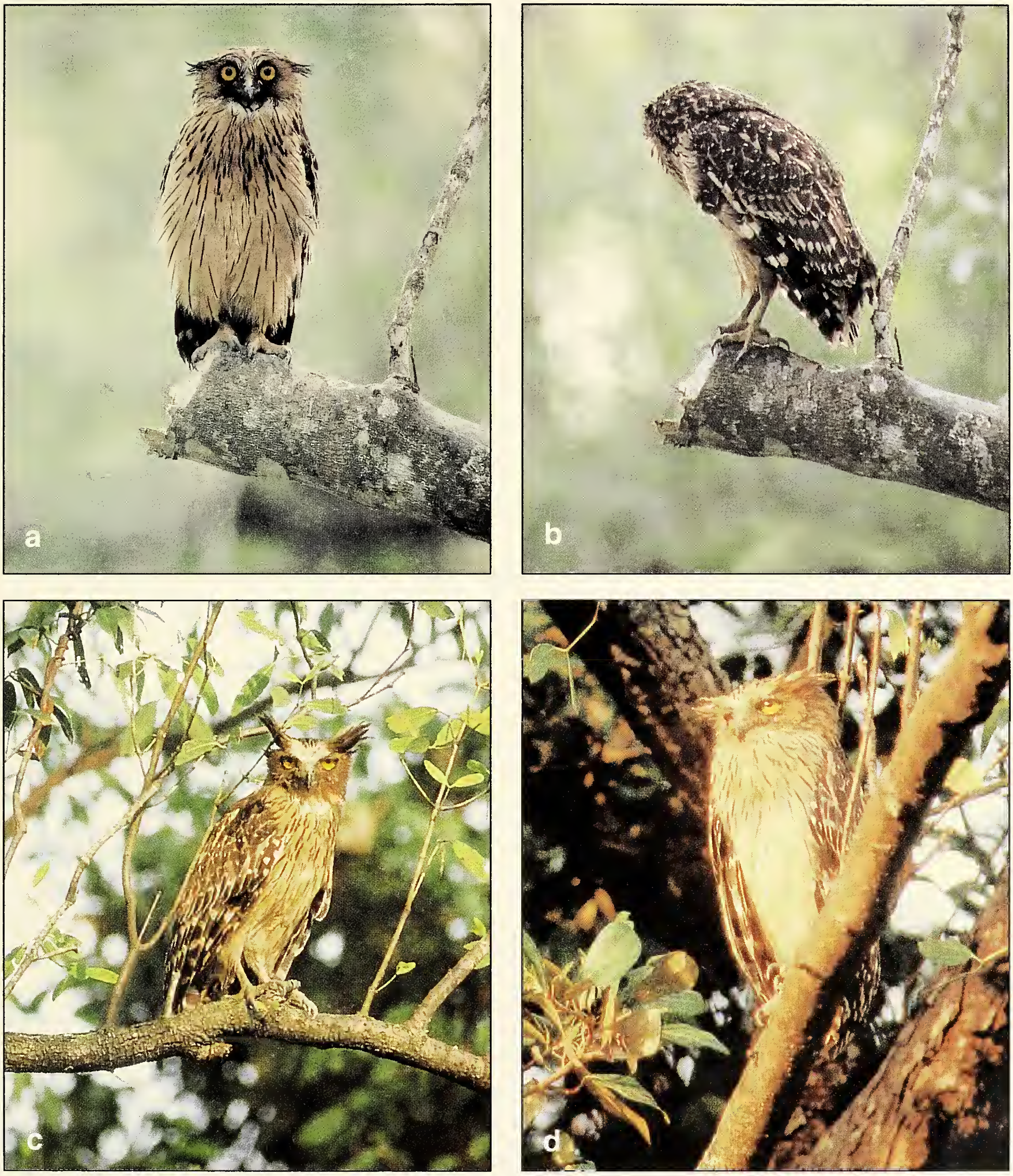

Fig. 1: Buffy fish-owl *Ketupa ketupu* in Sundarbans, Bangladesh
a. Individual 1 (front view), b. Individual 1 (side view), c. Individual 2, d. Individual 3

Sundarbans with the same affinity are the masked finfoot, and not to forget the Javanese rhino among the exterminated Sundarbans mammals. More careful observations in future will surely bring forth other interesting discoveries from the Indian and Bangladesh Sundarbans.

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26. A NOTE ON THE CIRCUMORBITAL SKIN COLOUR OF INDIAN GREY HORNBILL *OCYCEROS BIROSTRIS*

On August 8, 2000, I was attracted by the calls of Indian grey hornbills *Ocyceros birostris* (Scopoli) from a large fruiting pipal *Ficus religiosa* Linnaeus, in my garden in Hyderabad. This was the third consecutive day that I was watching this trio of 2 males and 1 female. It was obvious they were courting, for the males displayed and postured with upright body and bill pointed skyward. While doing so, the feathers above their tarsi were puffed up, like small balls of white cotton. Their white-tipped tails were constantly and rhythmically pumped in an arc (swung like a pendulum if the birds were viewed in profile) from their normal positions, inwards. Their loud calls resounded through the garden. Males uttered a shrill and quavering squeal, while the female's call was a clearer and louder, nasal "wheeeee". The birds also uttered a ratchety "k-k-k-k-k-k-krrr" (maybe only male) as they moved upward, towards the top of the tree. All three birds hopped and clambered about in the tree, using their bills to pull themselves up at times, plucking and eating figs as they proceeded. Twice a male hopped along a branch towards the female and acted as if he was going to feed her, though no item of food was passed.

I got a very good view of all three as they moved about. I noticed almost immediately that the circumorbital skin on the female was a rich dark orange and her irides were dark brown. Both the males had black circumorbital skin and orange irides. While the colours of these soft and bare parts of a male are recorded in published literature (Ali and Ripley 1987, Baker 1927, Kemp 1995, Roberts 1991), there is no mention of the circumorbital skin colour of a female Indian grey hornbill (Kemp 1995).

On August 29, 2000, I was in Mumbai and took the opportunity to check the specimens in the collection of the Bombay Natural History Society. I examined 11 females, of which 9 had clear orange skin around the eyes. The circumorbital skin colour was not clear on specimen # 11447, collected by P.T.L. Dodsworth on 13.i.1913 from Karka, N.W. Himalayas. A remark on the tag read, "Irides reddish-brown." Specimen # 11450, collected by V.S. Lapersonne on 29.v.1929 from Chitteri Range, Salem at 2,000, was marked as a female and had a quarter moon-shaped orange area below the eye. This specimen also had a relatively more prominent casque than that of the others.

It is, however, possible that the colours of bare skin and irides may vary according to the emotional state of the bird and the resulting endocrinal secretions. Outside of the breeding season, probably the bare skin of both sexes may well be dark grey to black, and that of the female changes only during courtship and times of excitement.

The shape of the casque, the extent of yellow on the bill, and the colour of the irides are used to separate sexes of the Indian grey hornbill in the field. These field-marks can now be supplemented by the differences in their circumorbital skin also.

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27. SIGHTING OF MALABAR PIED HORNBILL *ANTHRACOCEROS CORONATUS* IN SANJAY GANDHI NATIONAL PARK, MUMBAI

On July 30, 2000, during a walk in the Sanjay Gandhi National Park (SGNP), Mumbai, at 0845 hrs we stumbled upon a noisy flock of Indian grey hornbill *Ocyceros birostris*. There were four individuals to our left, coursing restlessly through the thick canopy about 40 m away. We were at an elevation and the birds, though about 10 m from the ground were exactly level with us. While we were contemplating the reason for such aggressive behaviour, another much larger and darker bird emerged from the thick cover. It was still partly hidden and difficult to identify, but as soon as it alighted from a tall *Adina cordifolia* tree, the white trailing edge on its predominantly black wings and white outer tail feathers disclosed its true identity. The bird being mobbed by the four Indian grey hornbills was the Malabar pied hornbill *Anthracoceros coronatus*. Soon, *A. coronatus* was chased away by the four birds and the flock disappeared into the canopy.

However, within five minutes these noisy hornbills returned to the same area, but perched slightly closer to us. This time there were two *A. coronatus*. One bird was identified to be a female from the absence of the black patch at the posterior end of its casque, while the sex of the other bird could not be determined. The four *O. birostris* always kept a close vigil, but never advanced too close to the larger species.

O. birostris has been observed to nest in this area, due to the presence of huge trees, and its aggression towards its conspecifics could be justified. However, both birds breed between March and June in their respective ranges (Ali and Ripley 1987), and a fight over a nesting site is quite unlikely in July. A detailed study is required to comment conclusively on it.

A. coronatus was never reported from Sanjay Gandhi National Park until February 6, 2000, when one bird was sighted by a group of bird watchers in the same valley, called the Pongam Valley due to a profusion of *Pongamia pinnata*. Subsequently, there have been a few confirmed and unconfirmed records of the bird from various parts of the Park.

According to Ali (1996), the bird is found in south and central India: north to southeast Uttar Pradesh, Bihar and Orissa. Grimmett *et al.* (1999) mention its distribution in the Western Ghats and east India.

Anthracoceros coronatus is mainly frugivorous, but can also subsist on small reptiles, mice and juvenile birds as has been reported by Ali and Ripley (1987). The present sighting of *A. coronatus* is almost six months after its first record from SGNP. It is evident, therefore, that the birds, which presumably strayed or were released into SGNP (a Tropical Moist Semi-deciduous Forest) outlived the harsh summer and acclimatized to their newly found home. Our next step should be to examine whether the species attempts to breed here, provided that both sexes are present.

Additional Note from first author

I was at Sanjay Gandhi National Park on March 9, 2003 and was fortunate to spot a female *A. coronatus* with a flock of *O. birostris* in precisely the same spot as the first sighting. Over three years have passed since *A. coronatus* was first sighted, and since then, a female bird has been regularly seen by many bird watchers including the first author near the Pongam Valley, moving boldly with a flock of *O. birostris*. It is, therefore, clear that the bird has adapted to the Moist Semi-deciduous Forest of SGNP. The most striking feature of the sighting is that the larger *A. coronatus* seems to be enjoying a congenial relationship with the smaller, but more numerous hornbill *O. birostris*. I have seen the two species in other forests of India as well, sometimes even sharing the same tree, but have never observed any significant interaction between the two. Thus, this three-year association between the two related yet distinct species is unique and worth mentioning — A.A.

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28. NOCTURNAL FEEDING BY WHITE-BELLIED DRONGO *DICRURUS CAERULESCENS*

Van Ashram situated on the outskirts of Sawai Madhopur city, has a Forest Rest House and a Range Office. A forest nursery is also present on the campus.

On May 14, 1999, while I was observing nocturnal animals in and around Van Ashram, at *c.* 2030 hrs, I came across three white-bellied drongos *Dicrurus caerulescens* hovering near an electric light bulb, in front of the Forest Rest House, devouring insects. All the three birds were perched on a wire. One more bird, feeding near another bulb, was perched on a bough of *Adansonia digitata.* I observed all the four birds up to 2200 hrs. When I left, they were still feeding. The following night, I saw perhaps the same birds feeding on flying insects.

Nocturnal feeding by black drongo *Dicrurus adsimilis*, inside human habitation, has been reported by Khan (1990), Nameer (1990) and Sharma (1991). The white-bellied drongo is more arboreal in nature than the black drongo, and it is a forest bird. It generally avoids human habitation. The gradual destruction of forests around the periphery of the expanding city and reduction in the food sources is perhaps forcing this bird to change its behaviour. Night light sources of the city attract huge insect populations from surrounding forest areas, with perhaps a resultant fall of insect density in surrounding forests. This in turn may lead to forest birds like the white-bellied drongos following their food resource for nocturnal feeding to the city.

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29. TOTAL ALBINISM IN A LARGE GREY BABBLER *TURDOIDES MALCOLMI*

On July 29, 2000, while I was surveying the biodiversity of Kumbhalgarh Wildlife Sanctuary, a milk-white large grey babbler *Turdoides malcolmi* caught my attention near Nandeshma village, on the outskirts of the Sanctuary. It was an adult bird with completely white plumage. The legs and bill were lighter than normal individuals. It was the only albino in a flock of eight birds.

When I approached the flock to get a photograph, the albino took off and hid in the foliage of a nearby mango tree, while the rest of the flock remained on the ground in a semi-alert posture. I waited motionless behind a *Butea monosperma* tree for the bird. When it came down after a few minutes, I tried going near, but this time too it took refuge in the foliage of another tree. After a few minutes, it alighted on a rock near its flock and this time I could photograph it [photographic evidence given by the author — Eds]. I observed this bird for nearly 15 min and found it to be quite shy compared to normal individuals.

Albinism has been reported in crows (Mahabal 1991; Abdulla 1997), doves (Javed 1992; Pandya 1994), redwattled lapwing (Soni 1992), Asian koel (Shyamal 1990), little grebe (Bharos 1996), coot (Parasharya *et al.* 1996), red-vented bulbul (Soni 1992; Joshua 1996), lesser whistling-duck (Chatterjee 1995) and common myna (Jha 1994). The large grey babbler is an addition to the list of albino birds, hence worth placing on record.

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October 16, 2000

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30. YELLOW-RUMPED FLYCATCHER *FICEDULA ZANTHOPYGIA* IN KERALA

On January 30, 1996 along the Mangala Devi trail at Periyar National Park, Kerala, I encountered a female yellow-rumped flycatcher *Ficedula zanthopygia*. The bird spent most of its time between 5-10 m up in the mid-canopy of trees on the edge of the forest. I watched the bird for about 20 min ranging at *c*. 8 m. I was familiar with the species from China and Thailand, identified it quickly and confidently and, knowing that it was a vagrant to India, made a quick sketch and a few hurried field notes. Some of the notes are reproduced here.

It was a distinctive bird that could perhaps only be confused with the female of the Chinese-breeding form of Narcissus flycatcher *F. narcissina elisae*. However, *elisae* can be distinguished, among other features, by the lack of the conspicuous yellow rump of the aptly named yellow-rumped flycatcher.

DESCRIPTION

Estimated to be about 10% larger and noticeably bulkier, more plump, proportionately larger headed and heavier billed than a red-throated flycatcher *F. parva*.

The upperparts were a fairly uniform dull olive-green; the nape was subtly greyer and the rump, undoubtedly the bird's most striking feature, was bright lemon yellow. This was visible at rest, when the wings were frequently held drooped, but was most conspicuous during the bird's short flights. The upper border of the rump fell level with the tip of the bird's shortest tertial while the uppertail coverts (and tail) were blackish and contrasted sharply.

The head was quite well marked. The ear-coverts were slightly greyer than the crown and nape and there was a narrow off-white band connecting the pale lores across the lower forehead. This, combined with the rather broad off-white eye-rings, created a bespectacled facial pattern reminiscent of the plumbeous vireo *Vireo plumbeus*.

The underparts were pale yellowish-white, somewhat scruffy in that the yellow tone was not evenly distributed but patchy. The vent and undertail coverts were clean white and there was some slight olive mottling, almost scaling, on the sides of the breast. The three innermost greater coverts had conspicuous blackish centres, broad white tips and narrower white fringes on the outer webs. Two, or possibly three, median coverts were similarly patterned with dark centres and whitish edges. The longest tertial also had a prominent white fringe.

The bill was entirely black, stout and heavy-looking, the legs a paler plumbeous grey, and the eye dark and appearing large.

The bird called several times during the observation — a dry, hollow sounding '*trrrrt*', that was mellower and softer than the similar contact calls of the red-throated flycatcher.

This was the second documented record of the yellow-rumped flycatcher from the Subcontinent. The first, a male in the Melghat Sanctuary in Maharashtra on the April 30, 1989, was documented by Haribal (1991). Interestingly, a bird answering the description of a female yellow-rumped flycatcher was apparently also present at Melghat in the winter of 1994-95. It was described to K. Kazmierczak by the local Forest Department staff who had been unable to identify it and were unaware of the previous record. There is another more recent report — a male observed by Steve Rooke and Deepal Warakagoda *et al.* in Sri Lanka on the March 7, 1999. (Steve Rooke pers. comm.)

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31. BREEDING RECORDS OF THE ASIAN BROWN FLYCATCHER *MUSCICAPA DAUURICA* IN SOUTHERN INDIA

Commenting on the status and distribution of the Asian brown flycatcher (*Muscicapa dauurica*), Ali and Ripley (1983) mention: "A partial migrant having a disjunct breeding range. Movements imperfectly understood." More specifically of its status in southern India, they say that the bird is a scarce breeder in the southern parts of the Western Ghats at about 900 m in North Kanara, Coorg, the Palni Hills and Cardamom Hills. It is also suspected that the flycatcher may breed in the Chitteri Range (Eastern Ghats) where it has been obtained in June, and in the Biligirirangan Hills (obtained in July). Post-dispersal of southern birds takes place as early as August. Ghorpade (1973) has mentioned it as a resident species in Sandur (E. Karnataka). Recently, Pittie (2000) recorded a young bird in June in Hyderabad.

My own records for the last two decades indicate that the Asian brown flycatcher could be resident in small numbers in the neighbourhood of Chennai city, Tamil Nadu and in the Rishi Valley area (Chittoor district, Andhra Pradesh). I have also seen a nest and a juvenile in the Peechi-Vazhani Wildlife Sanctuary in Trichur district, Kerala. I present the details below.

In Chennai, I have 12 records of the bird in the Guindy National Park and Theosophical Society estate during June-August (1984-1990). Usually single birds were noticed. Juvenile birds with spotted plumage were seen on at least two occasions — on July 29, 1984 and July 3, 1990 at the Guindy Park. On the latter occasion, an adult bird was also seen.

In Rishi Valley (*c.* 700 m), I have more than 20 records of the bird in June-August, when more than one bird was present on at least six occasions during these months. Juvenile birds were seen in July-August 1999 and in June-July 2000.

At the Peechi-Vazhani Wildlife Sanctuary (*c.* 100 m), a nest was seen on March 2, 1993, atop a dead tree at *c.* 17 m inside a hollow. On August 26, 1991, I had seen a juvenile with spots at Mannuthy close to the Sanctuary.

These records show that the Asian brown flycatcher may nest in suitable localities in small numbers in peninsular India, and more information can be collected by birdwatchers by careful observations.

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32. CRIMSON SUNBIRD *AETHOPYGA SIPARAJA SEHERIAE* IN MADHYA PRADESH

The crimson sunbird *Aethopyga siparaja* appears to have a patchy distribution in the Indian subcontinent. The subspecies *seheriae*, according to the HANDBOOK (Ali and Ripley 1987) and the SYNOPSIS (Ripley 1982), is a common resident from Kangra east to Sikkim (Himalayan foothills, subject to vertical movements) and thence south to the plains of eastern Bihar, north Bengal, Uttar Pradesh, hills of northeastern Peninsula and Orissa. The southernmost record for this subspecies is Balaghat in Madhya Pradesh.

The record of *Aethopyga siparaja seheriae* for Madhya Pradesh (Balaghat) is based on a single male specimen shot by D'Abreu at Laugher Ghat (*c.* 589 m) in the Balaghat district on April 1, 1913 (D'Abreu 1913). Since then, nobody has reported this bird from Madhya Pradesh.

I have been staying in the buffer zone (village Mocha) of Kanha National Park (22° 17' N, 80° 30' E) since November 1986 and my first sighting of this bird was in February 1992. It was a male (easily identifiable), hopping busily about the fire bush *Woodfordia fruticosa*, which was in full bloom. I was quite surprised to see this bird here, as there were no previous records of the species from around Kanha. Within a few days of my first sighting the male, I saw a female of this species which was not very difficult to distinguish from the female purple sunbird *Nectarinia asiatica*, that happens to be the only other resident sunbird species.

Though Laugher Ghat in Balaghat district is not very far from where I saw the crimson sunbird pair, I thought this was another case of strayed birds as there were no subsequent records from Madhya Pradesh after 1913. I observed this pair for a month or so in the early morning hours, mainly around *Woodfordia fruticosa* shrubs, the flowers of which were heavily laden with nectar. The *Woodfordia* shrubs stopped flowering by March end, and the sunbirds too disappeared. To my surprise, a male crimson sunbird returned to my garden in February 1993, which coincided with the flowering of *Woodfordia fruticosa*. The bird disappeared in March. Since then, a male crimson sunbird has been visiting my garden almost every year, arriving in February and leaving around the last week of March or April. In 1995, a male arrived in the last week of January and stayed on till the end of March. I have never seen a female of this bird since February 1992. I am not sure whether the male, which has been arriving here is the same individual or not. In February 1999, once again a single male arrived and was going about its business as usual. What surprised me was that the bird did not return after the *Woodfordia fruticosa* stopped flowering. The bird was seen all through the hot summer months the last sighting being on June 4. The bird was not seen throughout the day, but was seen every evening returning to roost on a small mango tree near my house.

The regular sighting of this bird around Kanha (in winter months) definitely proves that the bird winters here and probably stays till mid-summer before returning to the foothills of the Himalaya where it breeds. Another point is that perhaps it visits more areas in eastern Madhya Pradesh and the range of the bird definitely includes parts of the state other than the one single spot as recorded by D'Abreu in 1913.

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33. INCUBATION PERIOD OF CRIMSON SUNBIRD *AETHOPYGA SIPARAJA*

The crimson sunbird *Aethopyga siparaja* is a resident and fairly common bird in Konkan, Maharashtra. We see this brilliantly coloured sunbird in its restless flight in gardens, groves and dense forest regularly. According to Ali and Ripley (1999), the nesting period of this bird is April to July, but we have seen a female of this species building a nest on August 12, 2000 in Chiplun, Ratnagiri district, Maharashtra. The nest was built just outside a house wall in an urban area.

The pendant nest was entangled to a coir string, which was tied to a rafter of the house, 96 cm above the ground. This pear-shaped nest was 13 cm long, 7.5 cm wide and with an 8 cm awning over the entrance. The entrance was 3.5 cm in diameter.

We observed the nest a couple of times every day. On August 21 at 0700 hrs, there was only one egg in the nest. Two more eggs were added to the nest in the next two days. The female started incubation only after the third egg was laid. The male was never seen incubating the eggs.

The first egg hatched on September 6, 2000 at 0700 hrs, while the second hatched at 1400 hrs on the same day. The third egg hatched two days later in the morning. The incubation period for each egg was 16, 15 and 16 days respectively. Both the parents fed the chicks, but most of the work was done by the female, while the male took very little part in it.

All three chicks fledged on September 21, 2000 at 0800 hrs.

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34. THE SPANISH SPARROW *PASSER HISPANIOLENSIS* FOUND NESTING IN HANUMANGARH DISTRICT, RAJASTHAN

On March 26, 1999, we were at Badopal Lake, Hanumangarh district, Rajasthan watching migratory birds on passage. Large mixed flocks of Spanish sparrow *Passer hispaniolensis* and house sparrow *Passer domesticus* were conspicuous in the area, mainly around the ripe wheat fields and *Acacia tortilis* plantations along the road. The flocks of Spanish sparrow were exceptionally vocal, calling incessantly and seeming very restless. The whole area was alive with their noisy and restless behaviour.

After watching the birds on the lake in the morning, we retired to the shade of the plantation for lunch, where the Spanish sparrows were calling feverishly. While watching the birds, we noticed a few nests on *Acacia tortilis* trees. A few males in breeding plumage were loudly calling "*che che che* ...." while displaying with their tails cocked up and moving actively around the nests. Two males were noticed mounting females.

We counted 22 nests on six *Acacia tortilis* trees. These nests were about 6-9 m above the ground, made up of fresh straw collected from the nearby wheat fields. The nests were *c.* 25-30 cm in diameter, matching the dimensions given by Gavrilov (1963), and almost spherical in shape. Fresh straw was used on the outer surface of the nests. Most of the nests were on the biggest *Acacia tortilis* tree, located on its terminal branches.

On a second visit to the site on April 18, 1999, ten more nests were found. Two males were displaying with their tails cocked up, and six males were observed carrying some downy material (probably cotton from the nearby fields) and entering the nests.

The Spanish sparrow is a winter visitor to the northwestern part of the Subcontinent (Ali and Ripley 1987; Roberts 1992). It breeds extralimitally in Central Asia westwards to the Caucasus and eastwards throughout Kazakhstan. The birds start the return flight from their winter quarters to the native areas about the beginning of March. The establishment of colonies in breeding areas usually takes place a few days after the beginning of mass arrivals, during the middle or end of May. The birds usually nest in very large colonies (Gavrilov 1963). In contrast, the nesting colony at Badopal was very small and established as early as March.

The sparrow nests almost exclusively in cultivated areas, living in the proximity of man.

The availability of grain crops is one of the necessary conditions for these birds, and they seldom nest at any distance away from cultivation (Gavrilov 1963). Development of extensive plantations and agriculture during the last forty years or so in northern Rajasthan seems to have provided the Spanish sparrow with excellent living conditions conducive to establishing the first nesting colony in the Indian subcontinent.

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Note from the Referee:

The spread of grain cultivation and tree plantation in Rajasthan has nothing to do with this unusual nesting. Such favourable conditions have existed for nearly half a century over most of the Spanish sparrow's migration route. What is significant is the fact that a species known to be highly gregarious and colonial in nesting, has not done this before. Similar examples of greater flamingos and rosy starlings have been recorded from time to time, usually of abortive attempts by small colonies to nest in unusual locations. I was fortunate during a holiday trip to Kazakhstan two summers ago, to sit under a thorn tree roadside plantation in an otherwise treeless steppe grassland region, where above my head about 500 pairs of Spanish sparrows were nesting, so I can easily visualise what the authors saw in Hanumangarh district. Dissection of rosy starlings on passage in April/May has shown that their gonads are fully developed for breeding, and early writers like Ticehurst often speculated why they did not breed within the confines of India. Like the Spanish sparrow, small rosy starling colonies are often opportunistic, e.g. they have nested in the crevices between a stack of logs, and don't show great site fidelity for choosing their nesting site. The main motivation seems to be synchronous breeding, as is the case with the Spanish sparrow also. When the colony decides to leave, late fledglings are often left to starve in their nests! Huge colonies of over 1,000 birds do exhibit site fidelity, for obvious logistical reasons, but the central Asian breeding population of Spanish sparrows does have small offshoot breeding colonies, despite what Gavrilov wrote in describing huge breeding colonies in the *Journal*. The one I saw in Kazhakhstan was alongside a huge field bearing a crop of Safflower (*Carthamus tinctorius*), which is like a thorny thistle and then still in flower, so not suitable food for a sparrow. Otherwise, that colony had to depend entirely on small grasshoppers and wild grass seeds for feeding their nestlings. There were no cereal grain crops within miles and miles. This is why I feel it does not add to our knowledge when the authors speculate that favourable habitat was the reason for breeding in Rajasthan. The observation teaches us more about the needs of colonial and synchronous nesting species — T.J. Roberts.

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35. TERMITE REMOVAL FROM NEST MATERIAL AND REPAIR OF DAMAGED NEST BY WHITE-RUMPED MUNIA *LONCHURA STRIATA*

This refers to the note "Termite attack on nest material leading to desertion of eggs by birds" by K.V. Srinivas and S. Subramanya (*JBNHS 97(1)*: 145).

I have seen in Mangalore (during 1996-1999), usually old nests of spotted dove (*Streptopelia chinensis*), jungle babbler (*Turdoides striatus*) and white-rumped munia (*Lonchura striata*) being attacked partially or fully by termites after the birds have left the nest. The nests were built on small trees at a height of *c.* 1-3 m. During the late- and post-monsoon period, when the tree bark and nest materials dry up, termites from the ground reach the nest via the tree bark, which they cover with mud while tunnelling.

I also saw, on several occasions, live nests of white-rumped munia (built in thick bushes of *Piper nigrum* and its supporting tree *Erythrina* sp.), partially attacked by termites. Interestingly, the white-rumped munia feasted on the termites, a protein rich diet, in the nest material and nearby regions. Moreover, they repaired the damaged nest (as termites continue to attack the nest during night time and may damage part of the nest by early morning). The birds brought fresh nest material and successfully raised their offspring.

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36. BIRDS OF GOA — SOME SUPPLEMENTARY NOTES

Further to 'Birds of Goa' by Heinz Lainer (*JBNHS 96(2)*: 203-220; *96(3)*: 405-423), I had conducted a brief survey of the birds at three wildlife sanctuaries (Cotigao, Bondla and Bhagwan Mahaveer) between November 29 and December 9, 1995, as part of a survey of the great black woodpecker. These comments are based on the observations made then.

Besra sparrowhawk *Accipiter virgatus*

2 seen in Cotigao Wildlife Sanctuary (CWS); 1 seen in eucalyptus plantation, attacking smaller birds. All the earlier reports of this species are from Bhagwan Mahaveer Wildlife Sanctuary (BMWS).

Marsh sandpiper *Tringa stagnatilis*

1 seen at BMWS (Tambdi Surla area) on December 7. Reported as winter visitor in small numbers in the coastal belt.

Nilgiri wood-pigeon *Columba elphinstonii*

2 birds at CWS on November 30. Considered a scarce, erratic visitor.

Brainfever bird *Hierococcyx varius*

1 seen at CWS and 1 at Bondla Wildlife Sanctuary (BWS). Said to be usually present from mid-March to early November.

Drongo cuckoo *Surniculus lugubris*

1 seen in a mixed hunting party in CWS. Earlier recorded as an uncommon monsoon visitor — from late May to early October.

Small green-billed malkoha *Phaenicophaeus viridirostris*

A pair and a single bird seen at CWS. Said to avoid the Western Ghats strip.

Eurasian scops-owl *Otus scops*

4-5 birds heard calling at BWS. This bird has not been listed by Lainer (op.cit.).

Long-tailed nightjar *Caprimulgus macrurus*

1 heard at BWS. No recent records after the late 1970s.

Speckled piculet *Picumnus innominatus*

1 seen in a mixed flock in BWS and a pair noticed (also in a mixed flock) at BMWS. According to Lainer, this bird has been noticed just once earlier.

Indian pitta *Pitta brachyura*

2-3 heard at CWS. Said to be found from end April to early September and a few passage migrants seen between early January and mid-March.

Spangled drongo *Dicrurus hottentottus*

10-15 birds in flight at CWS; a pair at BMWS. Said to be a scarce winter visitor in small numbers.

Ashy woodswallow *Artamus fuscus*

5-6 in CWS; 1-2 heard at BWS and 4-5 in flight at BMWS. Said to be absent from large tracts during the dry season, being a monsoon visitor.

Scarlet minivet *Pericrocotus flammeus*

A juvenile female seen begging for food at BWS.

Indian scimitar-babbler *Pomatorhinus horsfieldii*

Calls heard at CWS. Recorded on the crest of the Sahyadri and, occasionally, down to an altitude of *c.* 70 m.

Grey-headed flycatcher *Culicicapa ceylonensis*

1 seen at BWS. Has been recorded only twice earlier.

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37. BIRDS OF TABO: A LESSER KNOWN COLD DESERT IN THE WESTERN HIMALAYA

The cold desert area of Tabo Valley (30° 05' N, 78° 28' E) lies *c.* 3,500 m above msl in the Spiti district, Himachal Pradesh State in northern India. This broad, flat valley is intersected by high, craggy, vertical cliffs of gray and brown sand. The higher slopes of the valley are covered with undulating alpine grasslands, which rise to the mountains, often up to the snowline or peaks (5,500-7,000 m). The boulder-strewn valley is also traversed by the River Spiti that enters through narrow gorges from the west, and flows down eastwards. The soil is alkaline (ph 7.2), poor in nutrients (K, Na, P) and organic matter (0.08%), and is silty, clayey as well as loamy (Singh and Gupta 1990).

The climate is cold and dry with heavy snowfall (*c.* 80 cm) in winter (December-March). Rainfall occurs only during September and October, and is scanty (10-15 mm). The temperature fluctuates from a maximum of 32.5 °C in August to a minimum of -32 °C in January (Kapoor and Bhagat 1990). High velocity winds blow throughout the year.

The vegetation of the area is xerophytic — dry alpine scrub, associated with soil moisture especially in the ravines and near water springs. The dominating species are *Hippophae rhamnoides*, *Rosa webbiana*, *Ephedra gerardiana*, *Caragana versicolor*, *Poa pratensis*, *Myricaria prostrata*, *Chenopodium hybridum*, *Cotoneaster falconeri*, *Lonicera spinosa*, *Capparis himalayana*, *Agropyron repens*, *Eragrostris* sp., and *Trigonella* sp., (Singh and Gupta 1990; Aswal and Mehrotra 1994).

A few trees of *Juniperus macropoda* and *J. semicarpifolia* grow naturally along the Spiti river and other watercourses. Plantations of *Populus alba*, *Salix fragilis*, *S. alba* and *Robinia pseudoacacia* are also present along the roadside in Tabo, raised under the 'Desert Development Programme' in 1985 (Negi 1985). The principal crops, cultivated only in flat areas having irrigation, are barley, millet, buckwheat (*Fagopyrum* sp.), potatoes and wheat.

As there was no record of birds from Tabo Valley, a survey was carried out from December 5-12, 1992. A total of 10 sites were selected from the entire Tabo valley (5-6 sq. km). Observations were recorded daily from 0900 to 1600 hrs. Data on the overall species richness, abundance, food, feeding habits and behaviour of birds in the area were collected. Winter was delayed that year, and as a consequence there was no snowfall in Tabo, making it favourable for birds (maximum day temperature 14 °C; minimum night temperature -18 °C).

Only 13 species of birds belonging to 9 families were observed in the study area.

Golden eagle *Aquila chrysaetos* (Accipitridae): Two adults and an immature bird observed flying and calling near high cliffs on the mountainous slopes north of Tabo village. In the afternoon, an adult was noted successfully preying on a woolly hare *Lepus oiostolus*.

Bearded vulture *Gypaetus barbatus* (Accipitridae): Two adults flying low over River Spiti, between rocky gorges, 3 km west of Tabo village, along the road to Kaza.

Chukor *Alectoris chukar* (Phasianidae): A small flock of five feeding on the ground under *Salix alba* plantation at Tabo. All birds hiding in a pile of boulders after sensing a red fox *Vulpes vulpes montana*. They came out of hiding after 12 min when the threat was over. Second sighting of 7 birds feeding in fallow terraced fields in the company of more than 17 blue sheep *Pseudois nayaur*.

Hill pigeon *Columba rupestris* (Columbidae): A small flock of nine feeding on wheat grains dropped on the road between Lari and Tabo, 3 km west of Tabo village.

Yellow-billed chough *Pyrrhocorax graculus* (Corvidae): Five individuals once observed flying and circling over Tabo village.

Red-billed chough *Pyrrhocorax pyrrhocorax* (Corvidae): Observed daily, three birds seen perching on rocky slopes near Tabo village.

Dark-throated thrush *Turdus ruficollis* (Turdinae): Eight birds observed feeding on insects on the ground under a *Robinia pseudoacacia* plantation along the road.

Guldenstadt's redstart *Phoenicurus erythrogaster* (Muscicapidae): A unique sighting of a large congregation (>25 individuals), all males. These birds inhabited a flat rocky area with stones and boulders beside a stream, with many fruiting bushes of *Hippophae rhamnoides*, 4 km west of Tabo village along the road to Kaza. Each individual feeding on the fruit and guarding its bush against intruders by flying over it and displaying its territory. One bird also observed on a *Salix* tree at Tabo village.

Grey-backed shrike *Lanius tephronotus* (Laniidae): A single shrike observed perching on *Salix alba* tree in an open, boulder-strewn, plantation. Seen searching for overwintering lepidopterous immatures in crevices of boulders.

Common great rosefinch *Carpodacus rubicilla* (Fringillidae): Small parties observed daily, feeding on seeds (pods) of *Robinia pseudoacacia* in a roadside plantation. A total of 28 birds seen.

Hodgson's mountain-finch *Leucosticte nemoricola* (Fringillidae): Common (>30 birds) around Tabo village and on rocky slopes.

Rufous-breasted accentor *Prunella strophiata* (Prunellidae): Small flocks, common in fields around Tabo village. Altogether 5 birds seen.

Tibetan snowfinch *Montifringilla adamsi* (Passerinae): Two birds once seen feeding on the ground in the vicinity of Tabo village.

The birds were identified using Ali and Ripley (1983, 1989) and Porter *et al.* (1981).

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38. OCCURRENCE OF *TRIOPS GRANARIUS* (LUCAS), CRUSTACEA: NOTOSTRACA, FROM MADURAI, TAMIL NADU

(*With one text-figure*)

Tadpole shrimps, considered as 'living fossils', are widely distributed in all continents except Antarctica (Whitehead 1990). The genus *Triops* has been reported from isolated localities in the Indian subcontinent (Packard 1871; Sars 1901; Kemp 1911; Walton 1911; Gurney 1925; Chacko 1950; Tiwari 1951, 1952; Longhurst 1955; Shanbhag and Inamdar 1968; Sanjeeva Raj 1971; Ghate and Shetty 1997). It is known for its intraspecific morphological variations that is, within the same species in different localities, hence it has been described under different specific names, adding to the taxonomic confusion within the genus.

This study reports the occurrence of *Triops* from Madurai, Tamil Nadu. About 20 mature live tadpole shrimps were collected near Thirumangalam (near Latibos India), Madurai (9° 58' N, 78° 10' E) during our survey on fairy shrimps in October 1996. Sizes of both male and female range from 1.8 to 3.9 cm. Species of this group have an elongate body, oval carapace covering the head, thorax and a variable portion of the abdomen (Fig. 1a). Shape varies from round to triangular, with rounded anterior margin between eyes, whereas the posterior margin is straight and slightly emarginated. Lateral edges of carapace bear small spines and edge of rear notch has short prominent spines. Sulcus is triangular with rounded emargination and wide base. Head bears an eye on the dorsal surface and reduced second antennae. The dorsal

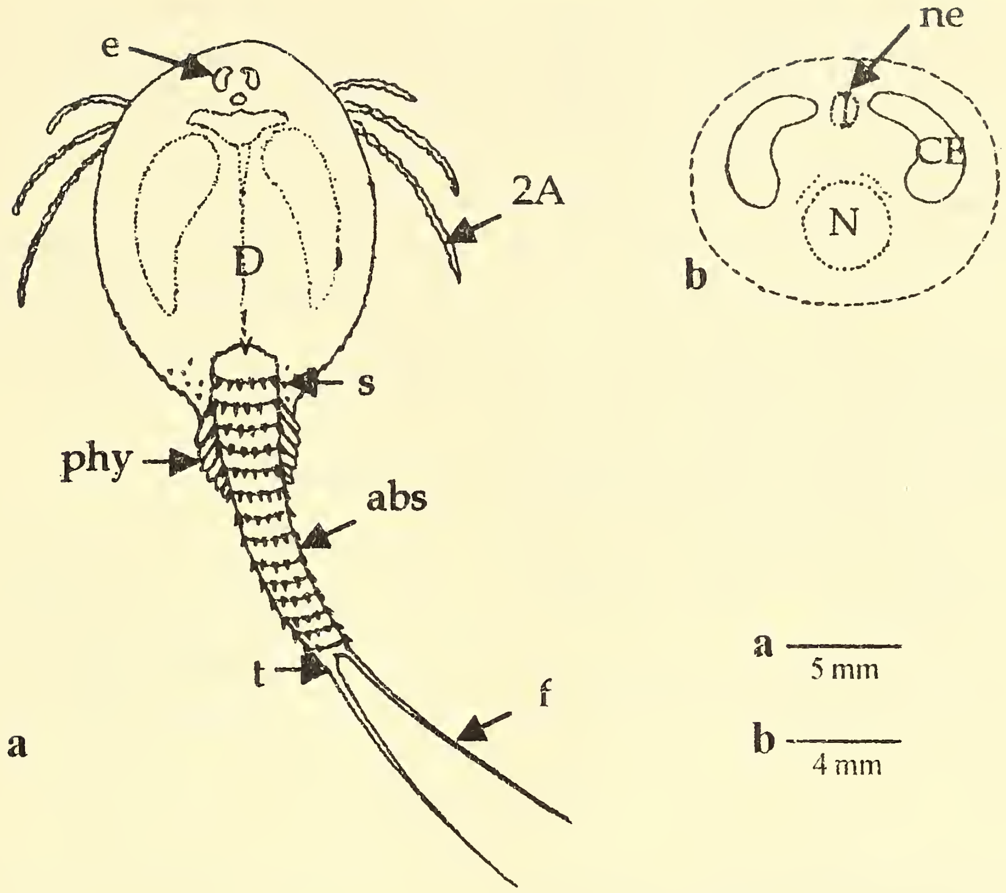

Fig. 1a-b: a. Diagrammatic representation of the notostracan *Triops granarius* (Lucas):
b. Higher magnification of the dorsal eye
D - dorsal shield, abs - abdominal segment, t - telson, 2A - second antennae,
CE - compound eye, e - dorsal eye, f - furca, ne - naupliar eye, N - neck organ, phy - phyllopods, s - sulcus

eye possesses a reduced naupliar eye and a neck organ between the kidney-shaped compound eyes (Fig. 1b).

Abdomen has 35 movable somites, about 15 of which are exposed beyond the carapace. Nine apodal segments possess prominent chitinised brown dorsal and ventral spines. Telson is broader and consists of 4 dorso-medial spines, 3 strong setal spines and small denticles, 6 posterior marginal spines, 4-5 lateral spines and 5 furcal spines. Furca is slender and longer than carapace, with serrated spines. Eleven pairs of thoracic appendages, namely phyllopods, one on each of the eleven body segments are used for locomotion. First pair consists of two segments separated by a joint chitinous cuticle, which allows bending of one segment upon the other; they have a sensory function and are used for capture of prey. There are 50 pairs of legs, gradually decreasing in size from the genital apertures; they are known as "abdominal appendages" and are used both for feeding and locomotion. Reproductive mode varies on a geographical basis, northern forms being hermaphroditic while southern populations are bisexual. In general, males are rare in the genus *Triops*. Gurney (1925) reported males outnumbering females in his collection (=*Apus asiaticus*) and Tiwari (1951) also agrees with Gurney's findings.

Notostracans are detritus feeders and predators. In the present study, it was collected along with anostracans and conchostracans. *T. orientalis* appears to be omnivorous and it has been observed to feed on bacteria, protozoa, *Daphnia*, copepods, small oligochaetes and also on *Streptocephalus* and Leptestheriied forms (Shanbhag and Inamdar 1968). *Triops* exhibits cannibalism, and even a small individual can easily eat a larger one. *Triops* is recorded as a pest of rice cultivation in different parts of the world such as Kashmir (Kemp 1911, Walton 1911), Spain (Font de Mora 1923), California (Rosenberg 1946) and Japan (Takahashi 1977). Fryer (1987) reported natives of the Federal District, Mexico using tadpole shrimps as food.

The genus is well known for its discontinuous distribution. Linder (1952) and Longhurst (1955) recognized only about 11 species, of which seven have wide geographic distribution. This classification has long been accepted 'even attaining the status of dogma' (Sassaman *et al.* 1997).

According to our study and other published records, only two species of *Triops*, *T. cancriformis* (Bosc) and *T. granarius* (Lucas) are known to occur in the Indian subcontinent. The former was reported in northern localities and the latter in the rest of India, particularly in the southern parts.

The authors are deeply indebted to the late Mr. Anthony Basil, Technical Officer, Madurai Kamaraj University, Madurai for accompanying them during the collections.

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39. OCCURRENCE OF RARE JUMPING SPIDER *HARMOCHIRUS BRACHIATUS* (THORELL) (FAMILY: SALTICIDAE) IN THE BANANA AGRO-ECOSYSTEM OF VADODARA, GUJARAT

While studying the spider diversity of the banana agro-ecosystem of Vadodara, we came across a rare jumping spider *Harmochirus brachiatus* (Thorell). It was first reported by Tikader (1976) from Pune, Maharashtra, India. There is no report of its occurrence thereafter. It is an addition to the spider fauna of Gujarat.

Adult male is *c.* 2.00 mm in total length, Carapace 1.1 mm long and 0.8 mm wide. Abdomen 0.8 mm long and 0.7 mm wide. The tibia and femur of the first pair of legs swollen and first leg always kept up in a defensive position. Because of the unique structure of the first pair of legs and their peculiar way of movement, this spider can be easily distinguished from other salticids. A closer view of the 1st pair of legs, shows a row of fringed hairs on the ventral and dorsal sides of the tibia, 3 and 2 pairs of ventral spines present on tibia and metatarsi respectively.

They move in the banana fields, on the pseudostem of the banana plant, and among the dry and decaying leaves of banana. Uncommonly seen in the pre-monsoon season (January-May).

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40. DESCRIPTION OF FEMALE *AMYCIAEA FORTICEPS* (CAMBRIDGE), ARANEAE: THOMISIDAE, WITH A REDESCRIPTION OF ITS MALE FROM KERALA, INDIA

(*With one text-figure*)

Amyciaea forticeps (Cambridge) is an ant-mimicking species of crab spider reported from India, Holland, Africa, Burma (=Myanmar) and Malaysia. Its resemblance to *Oecophylla smaragdina* (Fabr.) was studied by Mathew (1954). Tikader (1963) gave a description of this species in FAUNA OF INDIA based on a single male specimen collected from Pune. However, taxonomic literature regarding *A. forticeps* remains largely incomplete due to the absence of the description of a female. During our study of spiders of Ernakulam district, Kerala we came across several specimens of *A. forticeps*. On the basis of these specimens, a description and illustration of *A. forticeps* is given below.

Collection and preservation of the spider samples were done following Tikader. The material was studied using a Stereozoom binocular microscope; model Leica MS 5. All measurements are in millimetres, made with an eyepiece graticule.

Amyciaea forticeps (Cambridge)

(Fig. 1a-h)

1873 *Amycle forticeps* Cambridge, *Proc. Zool. Soc., Lond.* 1873: 122

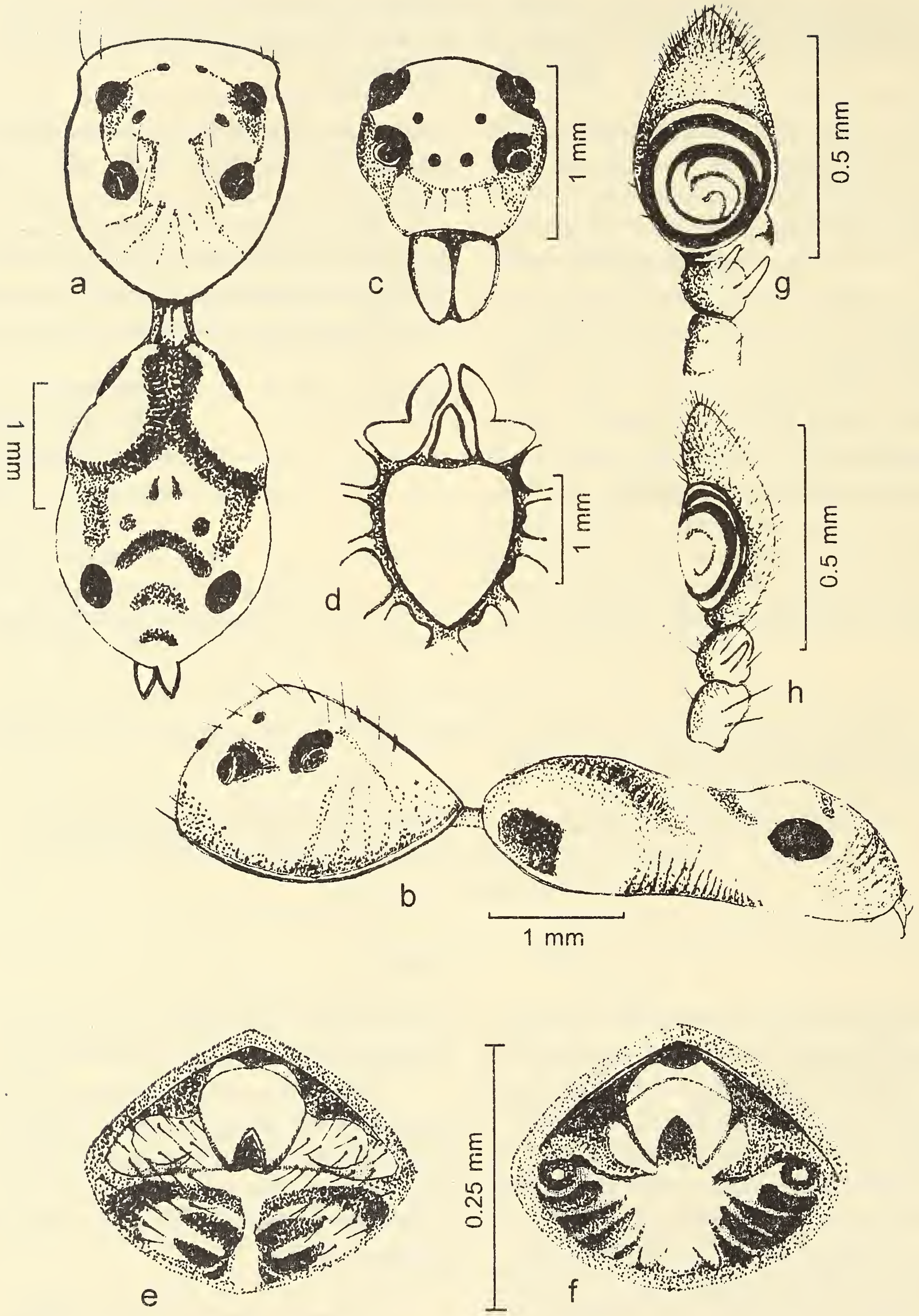
a
c
1 mm
0.5 mm
g
1 mm
1 mm
d
0.5 mm
h
b
1 mm
0.25 mm
e
f

Fig. 1: *Amyciaea forticeps* (Cambridge); a. Dorsal view of the female, b. Lateral view of the female; c. Front view of the face, d. Sternum with Labium and Maxillae, e. Epigyne, f. Internal genitalia, g. Palp - Ventral view, h. Palp - lateral view.

1885 *Amyciaea forticeps*: Simon, *Bull. Soc. Zool. Fr.* 10: 447.

1963 *Amyciaea forticeps*: Tikader, *J. Univ. Poona Sci. & Tech.* 24: 52.

1980 *Amyciaea forticeps*: Tikader, *Fauna of India: Spiders (Araneae: Thomisidae)* 1(1): 169.

Female: Measurements (in mm): Total length 5.5 L, Carapace 2.2 L & 1.3 W; Abdomen 3.2 L & 1.5 W. Legs I: 8.24, II: 7.92, III: 4.33, IV: 6.87.

Cephalothorax longer than wide, cephalic region strongly elevated and sloping in front, anterior margin of cephalothorax straight. Thoracic area sloping gradually, wider behind PLE, lateral sides steeply sloped. Cephalothorax reddish brown or pale orange, with a few body hairs. Fovea shallow and inconspicuous. Eyes recurved, in three rows, PLE and ALE encircled by inner white ring and outer black patch. Median eyes smaller than laterals, PME smallest, PME at the middle of two eye rows, ocular quadrangle wider behind. Eyes black, eye diameter ALE = PLE = 0.5 mm, AME = 0.25 mm, PLE = 0.1 mm. Clypeus high, twice the height of AME. Sternum heart shaped, 1.3 times longer than wide, anterior margin straight, clothed with minute hairs, pointed posteriorly, reddish brown or light orange in colour. Labium reddish brown, longer than wide, maxillae similar in colour to labium, scopulae present on the inner margin. Chelicera moderately strong, similar to clypeus in colour and height, with a few hairs on the outer margins, seven small teeth on outer margin and two large teeth on inner margin. Palp as in Fig. 1g-h. Legs long and slender, tarsus with two claws provided with minute hairs. Leg formula 1243. Legs resemble ant legs.

Abdomen longer than wide, anterior portion narrower, middle portion widest, two black eye-like spots on the dorsum on the posterolateral sides. A conspicuous inverted 'Y' shaped dark brown marking on the anterior half. Ventral side pale reddish-brown. A black spot at the anterior lateral end of the abdomen. Pedicel long. Abdomen clothed with fine hairs.

Male: Measurements (in mm): Total length 5L, carapace 2L & 1.1W, Abdomen 3L & 1.5W.

Cephalothorax longer than wide, reddish brown, narrowed anteriorly, broadest behind PLE. Cephalic region strongly raised and anterior margin slightly sloped. Thoracic area sloping gradually, posterior margin smoothly curved. Fovea long, shallow and inconspicuous. Clypeus moderately high, a little less than the separation of ALE. Ocular area as in female. Sternum reddish brown, longer than wide with truncate anterior end and pointed posterior end. Labium longer than wide, reddish brown. Maxillae similar to labium in colour. Chelicera moderately strong. Legs long, slender and ant-like, reddish brown in colour, tarsus and distal end of the metatarsus lighter. All segments uniformly clothed with minute hairs, few large bristles on femur, tarsus with two claws. Leg formula 1243. Pedipalp as long as tibia of leg I, MBA one, cymbium long straight and conical.

Abdomen longer than wide, reddish brown but lighter than carapace. Anterior end narrower, broadest behind the middle. Dorsum marked with an inverted 'Y' shaped dark brown marking and three to four transverse dark brown stripes

Table 1: Measurements of leg segments (in mm) of ♀ *Amyciaea forticeps* (Cambridge)

Leg	Coxa	Trochanter	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
I	0.43	0.18	1.98	0.43	2.16	1.98	1.08	8.24
II	0.36	0.29	1.62	0.54	2.09	1.87	1.15	7.92
III	0.29	0.11	1.08	0.29	1.08	1.01	0.47	4.33
IV	0.36	0.18	1.98	0.32	1.69	1.62	0.72	6.87

posteriorly. A black eye-like irregular spot on the anterolateral end near the pedicel. Spinnerets subequal in length. Dorsum has two hump-like prominences on the anterior and posterior end, with the middle being depressed, resembling an ant's abdomen. Ventral side pale reddish brown.

Materials examined: 2♀♀, location: Ernakulam 3.xii.2000, Coll: Samson Davis; 2♀♀, location: Cochin 2.xi.2000, Coll: Sunil Jose, K.; 2♂♂, location: Paravur, Ernakulam 15.xii.2000, Coll: Sudhikumar, A.V.

Natural History: Collected from leaves of *Mangifera indica* in the same habitats as that of *Oecophylla smaragdina* (Fabr.)

Distribution: INDIA: Ernakulam (Kerala State), Pune (Maharashtra); Burma (=Myanmar); Malaysia; Holland; Africa.

Remarks: According to Tikader, an eye-like spot is present on the posterolateral end of the abdomen in male, whereas this is absent in our specimens. Similarly, in the palp the embolus is coiled two and half times, whereas it was only one and half times according to Tikader. The black irregular spot present on the anterolateral end of the abdomen in both sexes in our specimen is also absent in Tikader's description. Since the specimens are similar to Tikader's specimen in all other characters, we believe this difference may be a geographical variation or due to an omission in description.

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41. RARE SIGHTING OF OGRE-FACED SPIDER *DINOPIS GOALPARAENSIS*, ARANEAE: DINOPIDAE, IN THE BANANA AGRO-ECOSYSTEM OF VADODARA, GUJARAT

(*With two text-figures*)

Dinopis is commonly known as the ogre-faced spider. Review of literature shows that this spider is poorly known from India. There is a single report of the occurrence of *Dinopis goalparaensis* by Tikader and Malhotra (1978) from Jamduar, District Goalpara, Assam. This note records the occurrence of *Dinopis goalparaensis* from Gujarat for the first time.

To study spider diversity in a banana agro-ecosystem an extensive survey was carried out in different banana fields situated in a 20 km radius of Vadodara city. Spiders were hand picked and preserved in 70% alcohol. The ogre-faced spider, attached to dry leaves of a banana plant, was collected from its web. These spiders have a flattened carapace, elongated abdomen and long slender legs. Because of these characters this spider superficially resembles the juvenile of *Eucta* sp. (Family: Tetragnathidae), however, it is easily differentiated from *Eucta* sp. by the following characters:

1. Posterior median eyes larger than the rest, black in colour, anterior median eyes smallest and anterior laterals present on

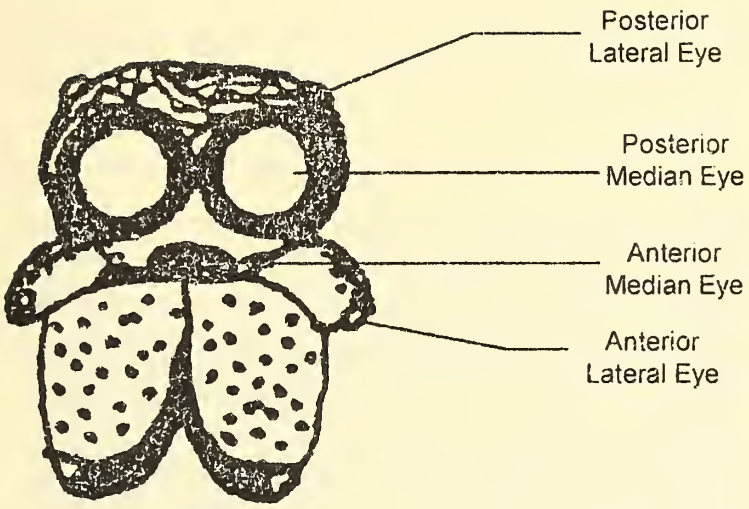

Fig. 1: Front view of face, showing arrangement of eyes

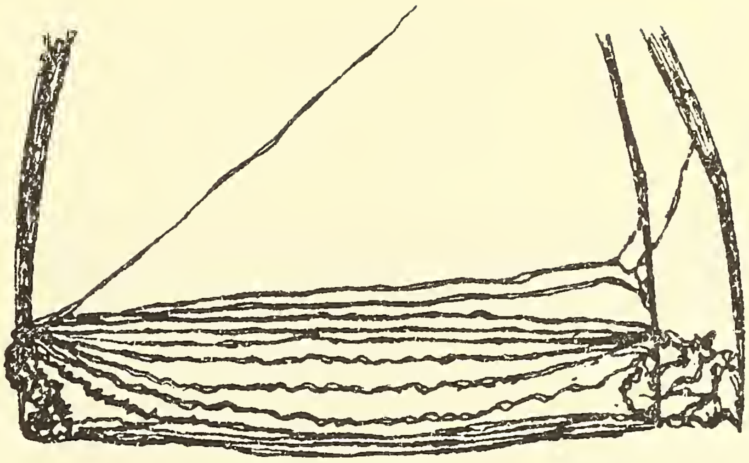

Fig. 2: Prey capture web held between the first two pairs of legs

tubercles which are pointing downwards (Fig. 1). In *Eucta* sp. eyes are smaller and equal in size.

2. Subadult female measured about 4.4 mm in total length, carapace 1.2 mm long and 1.0 mm wide, abdomen 3.2 mm long and 0.8 mm wide. However, adult female measures about 13.3 mm in total length (Tikader and Malhotra 1978), nearly equal to that of *Eucta* sp.
3. Abdomen long but not pointed at the posterior end (unlike *Eucta* sp.).
4. Legs long but very delicate as compared to *Eucta* sp.

Dinopis goalparaensis rests in its web, stretching its legs like *Eucta* sp., anterior legs extended forward and posterior legs extended backward.

It is a nocturnal weaver and constructs two types of webs: Orb web and Actual Prey capture web (Fig. 2)

The Orb web of *Dinopis* is similar to that of other orb weavers and it is not basically used for catching prey but for resting. The prey capture web is rectangular (like a tennis court net) and is held between the front legs by the spider, it consists of sticky silk threads.

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42. OBSERVATIONS ON *BAUHINIA MALABARICA* ROXB, LEGUMINOSAE: CAESALPINIOIDEAE, SHAPE OF CALYX IS NOT CORRELATED WITH SEXUAL NATURE OF FLOWERS

Roxburgh while commenting on *Bauhinia malabarica* Roxb. (in Carey ed., Fl. Ind. 2: 321. 1832) said, "This very distinct species is remarkable for the regularity of its five-parted calyx...”; de Wit (in Reinwardtia 3(4): 533-534. 1956) stated “...the calyx splits in Malaysian specimens in the upper part into two lobes, one consisting of two sepal-tops and the other of three. In some cases, the five tops become free.” He felt that the dimorphism might be connected with the sexual nature of the flowers, but he had not been able to demonstrate that the shape of the calyx was correlated with the sex of the flower. He further stated, “It is just possible that in India the tops of the sepals become always free and that this is connected with the flowers being male, which is confirmed by a few specimens from India which I was able to examine”. In the course of my study, I have observed that in the Indian specimens, the calyx is five-lobed in the upper part in the female flowers too. Thus, the shape of the calyx is not correlated with the sexual nature of the flowers.

In this connection, I would like to mention that fully developed male flowers are rarely found in herbarium specimens (see also de Wit in Reinwardtia 3(4): 533. 1956) because they remain attached to the pedicels just for a night and start falling from the next morning. Thus, during the flowering period, numerous fresh male flowers are found scattered under the tree, particularly in the morning hours.

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43. REDISCOVERY OF *CEROPEGIA EVANSII* McCANN, ASCLEPIADACEAE, FROM MAHARASHTRA

(*With one plate and one text-figure*)

Ceropegia evansii McCann (Asclepiadaceae) is an endemic and threatened plant species. The species is known to occur only from the hill ranges of the Western Ghats of Maharashtra i.e. Khandala and the neighbouring Sakarpathar-Ambavane range of Pune district (Ansari 1984, Jagtap and Singh 1999).

The species was first described by McCann from Khandala (1945). Santapau and Irani (1958, 1962) reported the species from the same hill ranges. The species was collected on July 27, 1964 by B.V. Reddi (93331) from Ambavane and deposited at the Botanical Survey of India (BSI).

About the occurrence, Santapau (1953) noted that the species is “one of the commonest of the *Ceropegias* in Khandala and is found abundant on the lower slopes below Duke’s Nose.”

The species has disappeared very fast from its type locality because of anthropogenic problems and habitat destruction. It has not been collected again from its type locality and other areas after 1964. This might be due to anthropogenic pressures and habitat destruction.

Ahmedullah and Nayar (1968) kept this plant under the rare and endangered category because of its localized distribution. In the RED DATA BOOK, Nayar and Sastry (1987) gave “vulnerable” status to the species. Almeida and Almeida (1990) have listed it as a threatened and endemic species. Singh and Karthikeyan (2000), Mishra and Singh (2000) have treated the species as critically endangered. According to the latter, the number of mature individuals in the wild is below 50. They have also reported that in 1997, a few plants were noted at Amba Ghat (Yadav, pers. comm.). Tetali *et al.* (2000) have treated it as vulnerable.

During routine botanical explorations, we have collected *C. evansii* from Rajgad, a hill fort, located in the Velhe taluka of Pune district in Maharashtra State (Fig. 1) at an altitude of 850 m. The present report is a rediscovery of *C. evansii* from a new locality other than

Tetali, P. *et al.*: *Ceropegia evansii* McCann PLATE 1

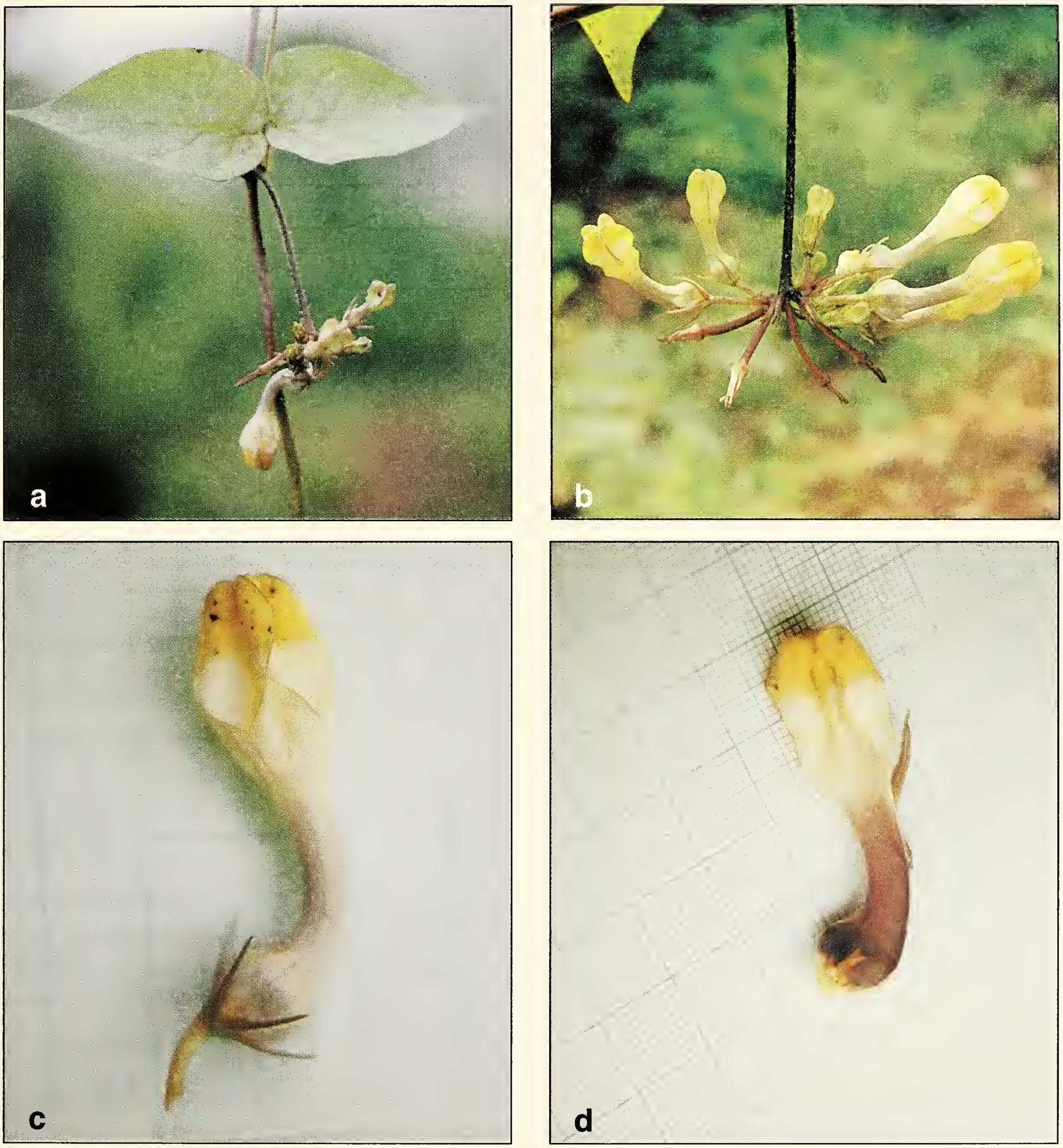

Fig. 1: *Ceropegia evansii* McCann
a. Habit; b. Inflorescence; c. Single flower; d. Vertical section of flower showing corona

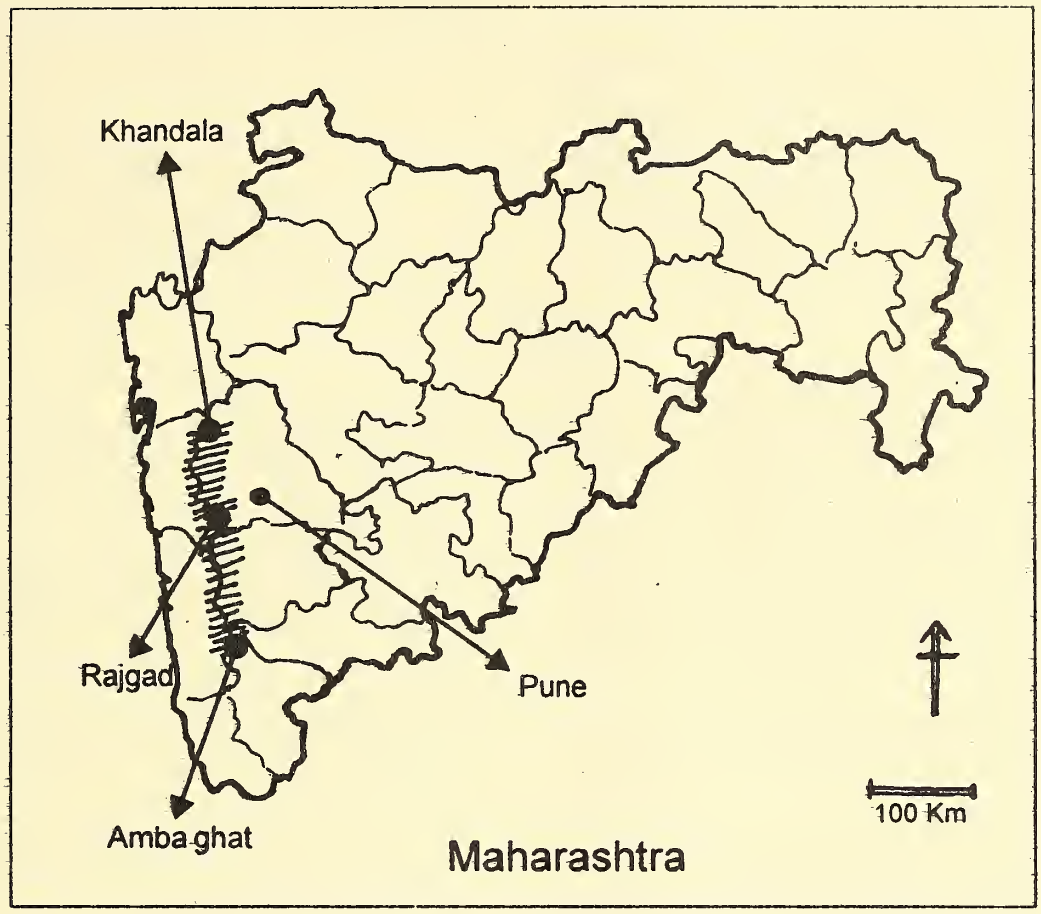

Fig. 1: Distribution map of *Ceropegia evansii* McC.

the Ambavane hill ranges (14.vii.2000 Tetali, s.n.).

We found only one individual in the entire locality, indicating extreme rarity of the species. The present collection site is 100 km away from, and southwest of the type locality.

The area where the specimen was collected is a degraded hill slope. The plant was found growing at the edge of a subtropical hill forest among *Lantana camara* and *Carissa congesta* bushes. The surrounding vegetation of the area is dominated by a gregarious shrub *Carvia callosa*. The area also seems to be the grazing ground for village cattle. Dozens of stray cattle were found grazing in the habitat. The cattle eat the entire plant. Cowherds and stray cattle appear to be a serious threat to the natural populations.

Information with regard to ranges in descriptions of certain morphological characters observed in comparison to the earlier description are as given below.

Twiners up to 3 m long (up to 2.7 m); petioles up to 2.5 cm long (up to 1 cm long); cymes consisting of few to many flowers, up to 13 (few flowered); peduncles up to 7.5 cm long (long *(sic)*); pedicels up to 1.3 cm long (up to 1 cm long); corolla 4.5 cm long (4 cm long). Various parts of the plant are shown in Plate 1 to facilitate identification.

The voucher specimens are deposited at the Herbarium, Botanical Survey of India, Western Circle, Pune (BSI), and Naoroji Godrej Centre for Plant Research, Lawkim Ltd. Campus, Shindewadi.

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Back: The cover of the Inaugural Vol. 1(1) (1886), surrounded by those of Vol. 96(1) (1999) Tiger in Sundarban by Sudheer Agashe; Vol. 97(1) (2002) Asian Elephant by an anonymous contributor; Vol. 98(1) (2001) King Cobra *Ophiophagus hannah* by Shekar Dattatri and Vol. 99(1) (2002) mass flowering of Karvi *Carvia callosa* by Ashok R. Kothari.

These illustrations represent some of the most spectacular aspects of the biodiversity of the Indian subcontinent.

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Editorial

The *Journal of the Bombay Natural History Society* was first published in 1886 as one of the major activities of the Society founded in 1883 to "stimulate lovers of nature to record and communicate their observations." The editorial to the first issue states, "In accordance with the character this Society has assumed from the beginning, the aim of its *Journal* will be as far as possible, to interest all students of nature, ever remembering that there are many naturalists, in the highest sense of the term, who have not such a technical knowledge of any particular branch of the science as to be able to enter with interest into questions of nomenclature and the discrimination of closely allied species." In the 117 years of its existence, the *Journal* has surpassed its modest objective and become one of the main sources of information on the biodiversity of the Indian subcontinent. In a publication history straddling three centuries and two millennia, it has achieved a remarkable standard of excellence comparable to other journals of international repute. For a natural history journal published by a private Society largely out of revenues derived from its membership subscriptions and with minimal support from the Government and other sources, it is indeed a praiseworthy achievement. The *Journal*, in its first fifty volumes, records the achievements of its amateur membership, remarkable in the study of the general ecology of the fauna of the Subcontinent and the taxonomy of both the fauna and flora of the Subcontinent. This establishes the *Journal* as required reading for the study of the Subcontinent's biodiversity. The Society's members through their contributions to the *Journal* established the credibility of the Society as a source for information on the conservation needs of the Subcontinent and the laws that were framed for the conservation of the Subcontinent were based on the contributions of the Society's members to the *Journal* on the status of wildlife and the need for their conservation.

In the second fifty years of its existence, the *Journal* has been dominated more by professional biologists rather than amateur naturalists and this is perhaps a reflection of the status of the study of natural history in the Subcontinent.

To quote Sálim Ali from in his editorial to the 50th Volume of the *Journal*:

> "The membership of the Society does not consist of scientific men alone, nor does it consist of naturalists pure and simple, nor altogether of persons who look upon natural history merely as an amusing pastime. It is a conglomerate of all these types. And this is not all, for while readers of the *Journal* include some who are mainly interested in large game animals, the interest of others centres chiefly on plants or snakes or butterflies or birds. Every branch of the study of animal or plant life, moreover, has its devotees among them. Some are interested in problems of evolution or systematics and taxonomy, others in field study and ecology, others in morphology and laboratory experiments, others in economics and applied biology or some other line of study, and yet others in nature photography. The effort to cater for all these polyglot tastes makes the task of editing the *Journal* one of absorbing interest, but by no means easy. The problem always is to maintain the golden mean, and the difficulties involved in the effort are such as the casual reader can have but a vague conception of. Since the *Journal* does not pay for contributions, it is seldom in a position to pick and choose material to any large

> extent; nor is it always possible to publish articles strictly in rotation as they are received. Such delay sometimes causes dissatisfaction among contributors, and in some cases, where, for instance a new species is described, deferred publication may even constitute a genuine grievance. It may happen that one particular issue contains a preponderance of articles on birds, or plants or fish or what have you, or it may contain more articles on systematics or morphology — 'dry-as-dust' as they are commonly dubbed — than perhaps the average reader or field student cares to be inflicted with. A howl goes up immediately. One member complains that the *Journal* is getting much too 'high brow' for a simple nature lover like him and therefore writes in to please accept his resignation from the Society! Another member complains of a following issue that the *Journal* has descended to the level of a story-telling magazine and is no longer a truly scientific publication, therefore he feels constrained to dissociate his good name from it! And so it goes on. One finds in the *Journal* too much of fish and too little of birds; another too much morphology and too little natural history; and the charges of similar excesses and deficiencies levelled at the editors are without end. Our sins of omission and commission are indeed bewildering!"

But they are not new, and that the *Journal* has survived them during the last 117 years, and even grown from strength to strength to enjoy the high esteem of scientific workers throughout the world would seem abounding proof that it has, on the whole, been conducted along the right lines.

J.C. DANIEL

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August-December 2003 Vol. 100 No. 2&3

TIGER ECOLOGY AND CONSERVATION IN THE INDIAN SUBCONTINENT

(*With one text-figure and one plate*)

K. Ullas Karanth[1]

Key words: Tiger, *Panthera tigris*, India, ecology, conservation, predation, social organisation, evolution

The tiger has served as an effective umbrella species in conserving many forms of biodiversity in the Indian subcontinent. During the last three decades, scientific research employing modern methods has generated reliable information on tiger ecology in a range of habitats in the Indian subcontinent. These studies show that tigers evolved as solitary predators of large ungulates, and their social organisation pivots around breeding females that try to maintain and defend home ranges. Across the Subcontinent, tiger population densities vary from a low of <1 tiger/100 sq. km to a high of 20 tigers/100 sq. km, depending primarily on densities of ungulate prey. Although over 300,000 sq. km of potential tiger habitat still exists in southern Asia, breeding 'source' populations for wild tigers are primarily confined to effectively protected reserves that occupy less than 2% of the overall landscape, the rest of which acts as a population 'sink'. Tiger demography is characterised by both high productivity and mortality. Consequently, the depletion of their prey base due to human over-hunting appears to be a major threat to tigers, besides habitat loss and poaching. After being persecuted for centuries and pushed to the verge of extirpation, tigers received official protection over the last thirty years. However, their future is still not secure because of newly emergent misplaced priorities in conservation policies. Protecting viable tiger populations in reserves and buffering them against incompatible human uses of their habitats must continue to be at the core of the conservation strategy if tigers are to survive this century and beyond.

INTRODUCTION

Saving tigers: a landscape species approach to biodiversity conservation

Through centuries, the tiger *Panthera tigris* has been a predominant cultural icon in the Indian subcontinent (Jackson 1990, Karanth 2001). At the same time, however, commoners, kings and colonial adventurers have ruthlessly persecuted tigers. Thereafter, since the early 1970s, several South Asian countries have tried to use the tiger as an umbrella species for wildlife conservation through species recovery plans like India's ambitious 'Project Tiger' (Karanth 2001). As a result, in the Indian subcontinent, about 13,181 sq. km temperate forest, 9,043 sq. km wet evergreen forest, 13,736 sq. km moist deciduous forest, 19,360 sq. km dry deciduous forest, 6,927 sq. km alluvial grassland and 873 sq. km mangrove forest have been proclaimed as protected nature reserves

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(Dinerstein *et al.* 1997), thereby benefiting a whole range of other species and the overall biodiversity in general. Thus, in the Indian subcontinent, survival prospects for biodiversity in its myriad forms are inextricably linked to effective conservation of tiger habitats. The anxiety that the focus on tigers is some form of benign neglect of other species is thus clearly not justified.

Beginning with Jim Corbett, conservationists have repeatedly predicted the imminent extinction of tigers in the Indian subcontinent for the last 70 years (Karanth 2001). However, these predictions have failed to materialise because of the ecological resilience of the tiger (Sunquist *et al.* 1999) and due to timely conservation interventions (Karanth 2001). On the other hand, governments have also exaggerated their conservation successes (Panwar 1987) based on "tiger numbers" they generated using demonstrably failure-prone techniques (Karanth 1987, 1999; Karanth *et al.* 2003). Such widely divergent perceptions about the fate of the tiger arise from inadequate scientific understanding of tiger ecology and conservation issues. The purpose of this paper is to briefly review tiger ecology in the Indian subcontinent based on recent and ongoing scientific studies and to explore future directions for tiger conservation.

Generating a knowledge base for tiger conservation

Many hunters and naturalists have produced anecdotal accounts of tiger biology during the past two centuries (see Thapar 2001 for some examples): accounts by Brander (1923), Champion (1929), Corbett (1944), Singh (1984) and Thapar (1989) can be cited as good examples from India. Although qualitative in nature, they provided useful insights into tiger biology.

Despite the widespread interest in tigers among hunters of the past, and more recently among conservationists, and despite the massive efforts and investments made to recover tiger populations, knowledge about the species remains scanty, even within the conservation community. Most popular literature published even today repeats the same old flawed clichés: that there are five 'subspecies' of surviving tigers; that the largest wild tiger population in the world exists in Sundarbans; that white tigers have conservation value; that there is a need for releasing captive-bred tigers into the wild to save the species; that we reliably know the tiger numbers in specific reserves, regions or even over the entire country; and above all, that human beings and tigers had lived in harmony during some past golden age, and therefore, special reserves that try to curtail incompatible human uses of tiger habitats are unnecessary now.

Although ecological studies of tigers within a modern scientific framework began forty years ago with George Schaller's pioneering work in Kanha (Schaller 1967) and have advanced tremendously thereafter as a result of research by other scientists, much of this new knowledge appears to have escaped the notice of wildlife managers and conservationists in the Indian subcontinent. Therefore, there is an urgent need to summarise this knowledge that can provide a foundation for effective action to save tigers.

Major scientific advances in understanding tiger ecology were made in the 1973-1985 period through radio telemetry studies in Chitwan, Nepal, under the Smithsonian Tiger Ecology Project (Seidensticker 1976, Sunquist 1981, Smith *et al.* 1987, Sunquist and Sunquist 1988, Smith 1993, Seidensticker and McDougal 1993). During the1990s, long-term ecological studies in Nagarahole (Karanth and Sunquist 1992, 1995, 2000, Karanth *et al.* 1999), Panna (Chundawat *et al.* 1999) and other areas of India (Karanth and Nichols 1998, 2000) that employed modern techniques such as radiotelemetry, camera trapping, dietary analyses and prey density estimation, generated substantial new knowledge about wild tigers. At the same time, new studies by taxonomists, geneticists, evolutionary biologists and biogeographers (Wentzel *et al.*

1999, Kitchener 1999, Kitchener and Dugmore 2000) generated fresh insights into issues of evolutionary origin, radiation, and classification of tigers. In the following section, I will try to provide a brief overview of this new knowledge about tiger biology in the Indian subcontinent.

BIOLOGY OF THE TIGER

Morphology

The tiger is the largest of all living wild cats. Its body is adapted for stalking and ambushing ungulate prey up to five times its own size. Its strong but light skeletal structure and powerful muscles permit speedy short rushes, leaps and grappling. The jaw muscles and long canines enable a strong bite necessary to quickly kill struggling prey. Although quite spectacular, the tiger's coloration and stripes camouflage it well in the forest brush (Karanth 2001).

The standard body measurements (Riney 1982) and weights of tigers in South Asia (Pocock 1929; Sunquist 1981; Karanth, unpubl. data) are as follows: body mass of 175-260 kg for males and 100-160 kg for females; total length of 270-310 cm for males and 240-265 cm for females inclusive of an 85-110 cm long tail. The height at the shoulder is 90-110 cm. Contrary to earlier perceptions, measurements obtained from tigers captured for radiotelemetry studies in the Indian subcontinent (Sunquist 1981; Karanth, unpubl. data) show that they are not smaller than tigers captured in the Russian Far East (Dale Miquelle and John Goodrich, unpubl. data).

Tigers possess 30 teeth, with 6 upper and 6 lower incisors, 2 upper and 2 lower canines, 6 upper and 4 lower premolars and 2 upper and 2 lower molars. The upper canines are 50-60 mm long, and the lower ones 40-50 mm. Like other cats, tigers have five front toes (only four leave prints) and four hind toes. The toes have sheathed claws that can be extended for grasping. Their large, round eyes possess excellent night vision and ability to detect movement, but appear to have poor colour discrimination capability. Their hearing is acute and is used to locate prey, but the sense of smell is used primarily for detecting scent from the ground or vegetation. The cat's sense of "touch", with its padded feet as well as long vibrissae, is critical for silent movement through dense cover. Tigers possess several scent glands around their cheeks, toes, tail and the anal region, like other cats do (Ewer 1985).

Evolution, radiation and taxonomy of tigers

Tiger evolution has been studied using fossil evidence and molecular genetic techniques (Hemmer 1987, Herrington 1987, Kitchener 1999, Kitchener and Dugmore 2000). Tigers belong to the family Felidae and the genus *Panthera*, within which they branched off as a distinct species even before lions (*Panthera leo*), leopards (*Panthera pardus*) and jaguars (*Panthera onca*) and were widely distributed over China and Southeast Asia even about 2 million years ago. Tigers had managed to expand their range northwards into Russia, Japan, the Bering land-bridge, and south and westwards into the Indian subcontinent and the Caspian regions by about a million years ago. By the beginning of the Holocene (about10, 000 years ago), tigers were found on the islands of Java and Bali, but not in Sri Lanka (Kitchener and Dugmore 2000).

The climatic changes that shaped the expansion of tiger range across Asia during the Pleistocene and Holocene primarily operated through changes in connectivity of land-bridges and landscapes, which in turn was driven by changes in sea level and vegetation patterns. These environmental factors led to the evolution and radiation of large ungulates, particularly several species of deer (Cervidae) and wild cattle (Bovinii), opening up an ecological niche for a large, solitary, forest predator (Sunquist *et al.* 1999).

Although tigers tolerate high ambient temperatures up to 48 °C in northern India, they are not adapted to the arid, water-scarce environments in which lions and leopards still survive. However, tigers can tolerate severe cold climate (-35 °C) in the Russian Far East. They live at altitudes ranging from sea level to 3,000 m sometimes crossing Himalayan passes at 4,700 m. Tigers occur in the cold Temperate Zone forests of northeastern Asia as well as in the hot, humid, wet or dry forests further south. In the Indian subcontinent, they are found in Tropical Dry and Moist Deciduous Forests, Evergreen and Mangrove Forests, Riparian Grassland-forests of the *terai* and in mixed subtropical forests of Himalayan foothills. Their distribution seems to be determined primarily by availability of large ungulate prey rather than by vegetation types (Sunquist *et al.* 1999, Karanth 2001).

The tigers that successfully evolved and adapted to these varied environments and prey types, now 'look' somewhat different in different parts of their range. Based on such perceived morphological differences, taxonomists had classified tigers into four subspecies (*tigris* in South Asia, *virgata* in the Caspian region, *altaica* in Russia, *sondaica* in Java) by the19th century. Four more tiger subspecies were described in the 20th century: (*amoyensis* in southern China, *balica* in Bali, *sumatrae* in Sumatra and *corbetti* in mainland Southeast Asia). These traditional "eight tiger subspecies" were segregated based on body measurements and pelage details (Hemmer 1987, Herrington 1987) obtained from very few museum specimens (Kitchener 1999).

However, more recent syntheses (Wentzel *et al.* 1999, Kitchener 1999, Kitchener and Dugmore 2000) of the genetic, morphological and biogeographic evidence suggest that this traditional classification of "eight subspecies" of tigers is not reliable. New data suggest that morphological variation in tigers occurs along a gradient, rather than at the level of discrete subspecies. Therefore, the more plausible current models of tiger evolution lump all mainland Asian tigers into one or two subspecies that are distinct only from the other subspecies from the Sundaic Islands. Tigers now surviving in Russia, China, Indo-China and southern Asia, all appear to belong to one subspecies that is distinct only from the island subspecies surviving in Sumatra. Such studies also highlight the critical importance of representatively conserving the much wider range of ecological and behavioural variations in wild tigers as adaptations to their specific habitats, rather than merely trying to save traditional "subspecies" (Wikramanayake *et al.* 1998, Karanth 2001) that have little basis in reality.

Communication and social behaviour

Communication and sociality:

Because tigers are solitary animals that live at very low densities (Sunquist 1981, Sunquist *et al.* 1999), communication between individuals, either to seek out or to avoid one another, is crucial for maintaining their social organisation. The tigers' communication system involves an elaborate repertoire of chemical, visual and vocal signals. Common chemical and visual signals include exuding scent mixed with urine and scats, leaving visual marks by scraping or rolling on the ground and clawing trees (Smith *et al.* 1989, Smith 1993). A variety of long and short-range vocal signals, including roars, grunts, growls and purrs are also used. Among all these modes of communication, spraying scent mixed with urine is perhaps the most effective one overall (Sunquist 1981, Smith *et al.* 1989).

Using a combination of such signals, tigers communicate information on their individual identity, time of passage, social status, sexual receptivity and range-ownership to other tigers, thus enabling contact or avoidance, depending on the social context. With such a communication system, tigers maintain their social organisation with relatively few aggressive encounters that can have fatal consequences for the animals involved.

Sexual behaviour:

Tigers appear to mate throughout the year in the Indian subcontinent (Sunquist 1981; Smith 1993; Karanth, unpubl. data). Tigresses advertise their oestrous status through increased bouts of roaring and scent marking that help male tigers find them. The mating session lasts from 2-7 days and involves dozens of copulations of about 15 seconds duration every day. Mating tigers indulge in a lot of aggressive play. The tip of the male's penis has backward pointing 'spines', which may provide stimulation to induce ovulation in the female (Ewer 1985). Once the mating period is over, the two animals go their own separate ways.

Relationship between mother and cubs:

Following a gestation of 102-108 days, litters of 2-5 (usually 3) cubs are dropped in a secluded hideout. The cubs are born blind and helpless, and, are aggressively protected by the tigress. However, rarely, through a temporary hormonal imbalance, a tigress may kill or even eat her newborn cubs. The cubs are nursed on milk for the first two months and effectively hidden from other predators and even other tigers. Because the tigress must nurse and guard her cubs closely, her home range shrinks to a fraction of its usual size (Sunquist 1981, Smith 1993). When the cubs are 2-3 months old, the tigress starts to take them to her kills. At about 12 months old, they accompany the mother over her entire home range (Schaller 1967, Sunquist 1981, Smith 1993). Cubs learn to hunt by watching their mother. Sometimes, several prey animals may be killed within a few hours, when the tigress teaches her cubs to kill effectively.

Sometimes, the adult male that sired the cubs may temporarily associate with the tigress to share a kill or even play with the cubs (Schaller 1967, Thapar 1989). A tigress with cubs may sometimes share kills with her older daughter, who may have her own litters, leading to temporary associations of 7-8 related tigers. On the other hand, the tigress zealously guards her cubs from strange males, which often exhibit the infanticide behaviour common to many mammalian species (Smith 1993; Karanth, unpubl. data).

Between 12-18 months age, tiger cubs acquire their permanent teeth and become proficient killers. They learn to search, stalk, capture and kill potentially dangerous prey. By the age of 18 months, juvenile males make forays away from their mother's range to begin a transient life. Juvenile females stay close to their mother, but eventually disperse by 20-28 months, as their mother becomes increasingly aggressive towards them (Smith 1993). By then, the tigress would have come into oestrus again and mated.

Population structure and social organisation:

The structure of the typical tiger population can be described in terms of the sex and age categories of its members. Tigers of both sexes can be categorised into demographic stages (Karanth and Stith 1999) such as cubs (less than 1 year old), juveniles (1-2 years old), post-dispersal floaters or transients (over 2 years old) and breeding adults (3-12 years old). A few of the transients may also be old or incapacitated breeders evicted from their ranges by more vigorous successors.

Tiger social organisation pivots around breeding females that maintain fixed home ranges within which they try to raise cubs. These tigresses acquire ranges by evicting previous residents, or by 'inheriting' a part of their mother's range (Smith *et al.* 1987, Smith 1993). Normally, in a good habitat stocked with enough prey, a tigress starts to breed at 3-4 years. Her normal residential tenure is of 5-7 years, after which she loses her range to a competitor. The degree of spatial overlap (or lack of it) between neighbouring female ranges varies, depending on prey density and other ecological factors (Sunquist 1981, Smith *et al.* 1987, Miquelle *et al.* 1999, Karanth and Sunquist 2000). Adult males have larger ranges that overlap ranges of several breeding females, the average being about three. The degree of exclusiveness of male ranges is variable, depending on factors that are as yet unclear. The land tenures of breeding males are shorter (2-4 years) than those of females (Sunquist 1981, Smith 1993).

Although the ranges of neighbouring female tigers were exclusive in Chitwan (Sunquist 1981, Smith *et al.* 1987, Smith 1993), there appears to be some overlap in Nagarahole (Karanth, unpubl. data). In Chitwan, male ranges were mutually exclusive, but this was not clear in Nagarahole. In Chitwan and Nagarahole, the size of breeding female ranges varied from 13-30 sq. km and that of males from 40-100 sq. km (Sunquist 1981, Smith 1993, Karanth and Sunquist 2000). In Panna Reserve in central India, where tiger habitats are just beginning to be restored through protection, the range sizes were 243 sq. km for a male and 27 sq. km for a female, respectively (Chundawat *et al.* 1999). While female range size seems to be determined primarily by prey abundance, the size of a male's range appears to be a function of the number of female ranges that he manages to cover.

At about 18-28 months age, juveniles either leave their natal ranges or are evicted by their mother to become transients. Such floaters, particularly males, criss-cross several breeder ranges and even disperse away into new areas. These transient tigers have large ranges, which may cover an entire ecological unit. During a six-month period, two transient males had ranges of 99 and 77 sq. km in Nagarhole and the latter's range shrank to 44 sq. km when he acquired a breeding range (Karanth and Sunquist 2000). Radiotelemetry studies in Chitwan (Smith 1993) showed 10 dispersing males travelled an average distance of 33 km, and four females a distance of 10 km, before establishing their own ranges. However, occasionally such dispersers travel great distances of 100 km or more (Smith 1993).

In productive tiger populations, there is intense competition for breeding ranges. However, breeders of both sexes tolerate the passage of their transient offspring within their ranges and transient siblings seem to tolerate each other. However, when a breeder male is replaced, the new male systematically kills cubs of resident tigresses within his range. Through such infanticide, the tigresses are induced to come into oestrus again and mate, thus conferring an evolutionary advantage to the male through propagation of his genes (Smith 1993).

Predatory behaviour and ecology

Prey types and prey selection:

The need to hunt alone and kill large ungulate prey has been the driving force behind evolution of tigers (Seidensticker and McDougal 1993, Sunquist *et al.* 1999). Although tigers kill prey ranging in size from frogs to adult gaur (*Bos gaurus*) — the bulk of their requirement must come from deer, pigs, and wild or domestic cattle, that weigh between 20-1,000 kg (Sunquist *et al.* 1999, Karanth 2001). Apart from livestock, the principal wild prey of tigers in the Indian subcontinent include: wild pig *Sus scrofa*, sambar *Cervus unicolor*, barasingha *Cervus duvaucelii*, red deer *Cervus elaphus*, chital *Axis axis*, hog deer *Axis porcinus*, muntjac *Muntiacus muntjak*, nilgai *Boselaphus tragocamelus*, chousingha *Tetracerus quadricornis*, chinkara *Gazella bennettii*, blackbuck *Antilope cervicapra*, gaur, wild buffalo *Bubalus bubalis*, takin *Budorcas taxicolor*, goral *Naemorhedus goral*, serow *Naemorhedus sumatraensis*, and, occasionally, elephant *Elephas maximus* and rhino *Rhinoceros unicornis* calves. Tigers also opportunistically kill and eat other carnivore species such as sloth bears *Melursus ursinus*, leopards and dholes *Cuon alpinus*.

Activity and hunting behaviour:

Tigers hunt primarily after dark, when their superior vision confers an advantage (Sunquist 1981, Karanth and Sunquist 2000). Tigers tend to be active at the same times of the day when their prey are also active because they can more easily detect and home in on the latter. Consequently, human activities such as forest product collection and hunting that compel prey species to become nocturnal, also compel tigers to do the same.

Usually tigers become active at dusk, and remain so through the night until dawn. During hot parts of the day, they rest under shade, often lying up in water (Schaller 1967, Thapar 1989). Radiotelemetry locations in Chitwan and Nagarahole (Sunquist 1981, Karanth and Sunquist 2000) showed that tigers moved around a lot more at night (80% of locations) compared to midday (10% of locations). They typically remain active for about 6-8 hours in a day. The linear distances between radio-locations on successive days were 1-8 km (Sunquist 1981, Karanth, unpubl. data) although the actual distance walked overnight was more (5-25 km).

Tigers pad along forest trails and locate prey through hearing (in dense cover) or visually. Occasionally, they lie in ambush at localities favoured by prey, like water holes, clearings or salt licks (Karanth and Sunquist 2000). Some observers (Schaller 1967, Thapar 1989) guess that tigers have a 5-10% success rate while hunting. Because of difficulties in observing an unbiased sample of hunts, it is difficult to validate such estimates. However, success rates are likely to strongly depend on probabilities of encountering prey, and, therefore, on prey densities in an area (Karanth and Sunquist 1995).

After locating the prey, the tiger stalks it silently to get within range for a final rush of 15-30 m (Seidensticker and McDougal 1993, Karanth and Sunquist 2000), or longer across open clearings or waterbodies (Thapar 1989). The tiger usually attacks the prey from the flanks or rear, and knocks it down by the impact of its momentum and by grappling with its forelimbs. Simultaneously, it tries to bite the prey animal's throat or nape to immobilise it (Seidensticker and McDougal 1993). The tiger tries to keep away from the flailing hooves and horns of large ungulate prey. With dangerous prey such as adult gaur or buffalo, if the initial attempt to knock down and immobilise does not succeed, tigers may even give up the attempt. Sometimes, tigers get injured or killed by such quarry. After the prey animal is brought down, it is killed by strangulation or by rupturing of the cervical vertebrae, spinal chord, brain case or major blood vessels. Tigers deliver the lethal bite to the throat of larger prey animals, whereas smaller prey, such as pigs or chital may also be killed with a nape bite.

Feeding ecology:

Tigers in Nagarahole dragged their kills over distances ranging from 0-350 m (with an average of 51 m, for a sample of 133 kills), hiding the carcasses in dense cover unless the prey was too heavy (Karanth and Sunquist 2000). Tigers consume 20-35 kg of meat in their first meal, and unless disturbed, stay close by to guard their kills from other tigers and scavengers. Depending on the kill size and the number of tigers feeding, they stay with the kill for 1-7 days, eating two thirds of the kill including some fairly putrid meat. The remaining one third, comprising of larger bones, rumen contents and intestines is normally discarded (Karanth and Sunquist 2000). When hungry, tigers scavenge kills made by other tigers or by other predator species.

Killing and cropping rates:

Tigers are provisioned 1,825-2,190 kg meat/year in captivity (Sunquist 1981). A female tiger kills about 40-45 ungulate prey/year, consuming about 2,000 kg of meat (or about 3,000 kg of live prey), just for maintenance. The quantity of live prey consumed by adult males is higher (4,000 kg/year) and by juveniles and cubs is less. A tigress raising three cubs has to kill 60-75 ungulate prey/year (Schaller 1967, Sunquist 1981, Sunquist *et al.* 1999). Thus an 'average' tiger can be estimated to take about 50 prey animals or 3,000 kg of live prey annually (Schaller 1967, Sunquist *et al.* 1999).

Tigers may crop roughly 10-15% of available prey in an area annually, depending on how much prey is additionally killed by other predators such as leopards, dholes and human hunters. Considering the natural reproductive rates of ungulate prey, a 10% cropping rate translates into the requirement of a standing prey base of about 400-500 ungulates to support a single tiger through one year. Therefore, sizes of tiger home ranges depend on prey densities. Ranges of breeding female tigers vary from a low of 10-20 sq. km in prey-rich habitats to 200-300 sq. km or more in poor quality habitats (Sunquist *et al.* 1999, Miquelle *et al.* 1999). Therefore, more tigers can 'pack' into an area at higher prey densities, although social spacing behaviours may set an upper limit on tiger numbers. In the semi-arid area of Panna, availability of water and prey distribution (rather than prey abundance alone) influences tiger home range sizes (Chundawat *et al.* 1999, R.S. Chundawat, unpubl data).

Population ecology

Population densities:

Over most of their range, tigers coexist with other predatory carnivores such as leopards and dholes. The relative densities of each predator species in such guilds appear to be determined by the relative abundance of different size classes of prey in the assemblage (Karanth and Sunquist 1995, Karanth and Nichols 1998). Furthermore, as noted earlier, densities of tigers appear to be primarily a function of prey densities (Schaller 1967, Sunquist 1981, Seidensticker and McDougal 1993, Karanth and Sunquist 1995, Karanth and Nichols 1998, Sunquist *et al.* 1999, Chundawat *et al.* 1999).

As primary predators of large ungulates, tigers cannot sustain themselves or reproduce in the absence of such prey in sufficient numbers, even if smaller prey are quite abundant (Schaller 1967, Sunquist 1981, Karanth and Sunquist 1995, Sunquist *et al.* 1999). Recent studies that estimated tiger and prey abundance using rigorous methods (Karanth and Nichols 1998, 2000, Sunquist *et al.* 1999) clearly show a strong positive relationship between abundance of large ungulates and tiger densities.

As prey densities get lower, female ranges become larger, reducing the number of such breeders the area can support. Lower prey densities also appear to result in lower densities of transient tigers (Karanth and Nichols 1998, 2000). Because survival rates of cubs and juveniles are also likely to be lower at lower prey densities (Karanth and Stith 1999), the numbers of tigers in these two demographic stages will also be lower. Therefore, while other habitat-related or managerial factors may influence tiger density at a given site, prey abundance appears to be the most critical determinant.

However, accurately estimating tiger densities is difficult (Karanth and Chundawat 2002). The Indian Government's official pugmark censuses have often yielded unreliable results (Karanth 1987, 1988, 1999, Karanth *et al.* 2003). Camera trap sample surveys within a formal Capture-Recapture modelling framework has proved to be a good method for obtaining reliable tiger density estimates in well-protected study areas, particularly at higher tiger densities (Karanth and Nichols 1998; Plate 1, Figs 1, 2). Mean densities of tigers (excluding cubs <1 year) derived using the photographic Capture-Recapture approach in some typical tiger habitats in India were: Pench (Madhya Pradesh) 4.9 tigers/100 sq. km, Kanha 11.7 tigers/100 sq. km, Nagarahole 11.9 tigers/100 sq. km, Kaziranga 16.8 tigers/100 sq. km (Karanth and Nichols 1998).

The above cited density estimates show that alluvial grassland-forest mosaics of the Himalayan foothills and moist-deciduous forests of peninsular India potentially support the highest densities of tigers anywhere in the world (15-22 tigers/100 sq. km, including cubs). At the other end of the ecological scale, in the Russian Far East, tiger densities are as low as 0.5-1.5 tigers/100 sq. km (Miquelle *et al.* 1999).

Karanth, K.U.: Camera trapping of *Panthera tigris* PLATE 1

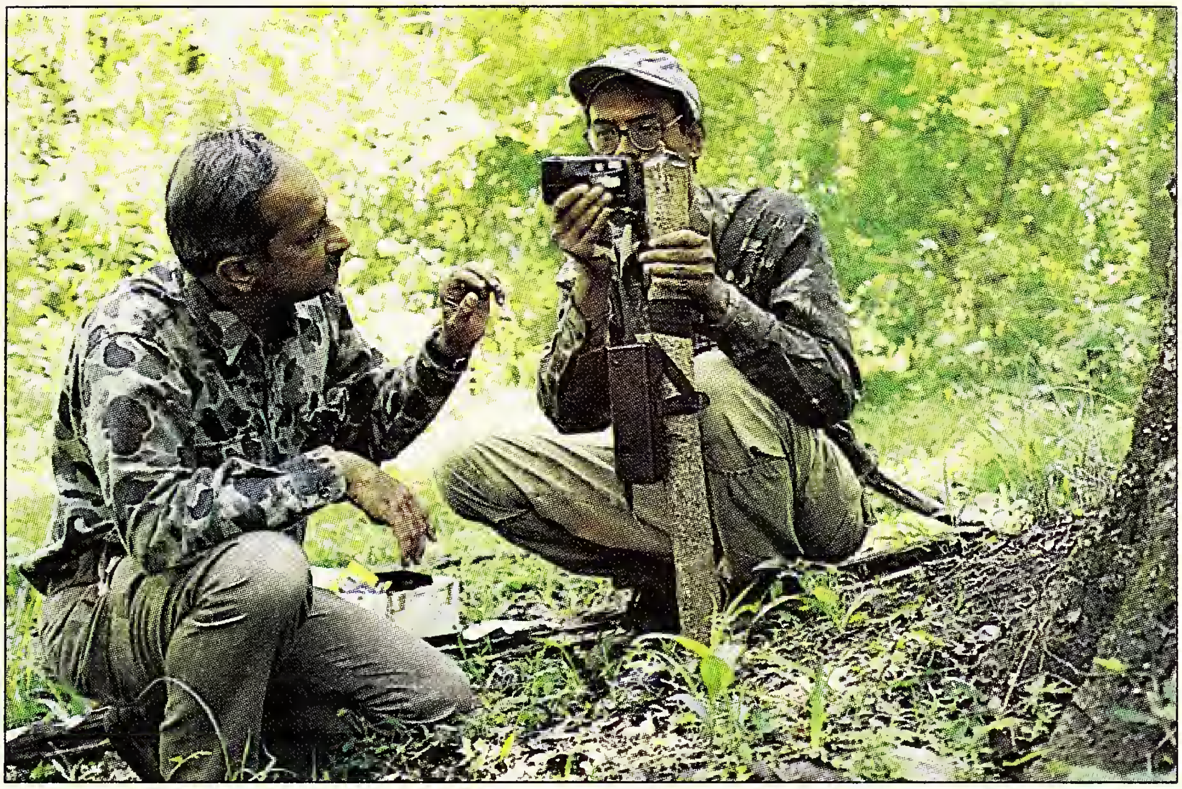


Fig. 1: Camera trap being set up for studying tiger density in Nagarahole National Park

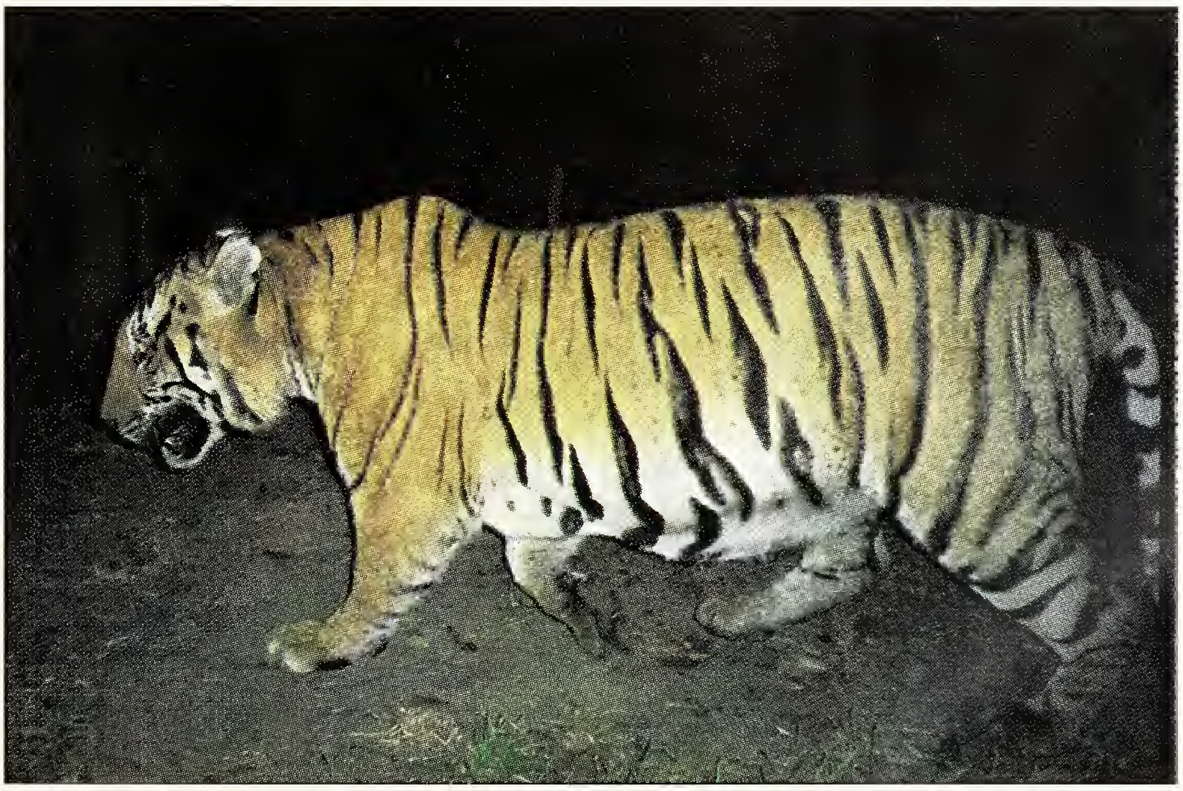


Fig. 2: A tiger 'photo-captured' by the camera trap

Fecundity and mortality rates:

In good habitats, tigresses appear to have an oestrous cycle of 20-30 days, beginning at around 2 years of age or earlier, but they conceive and produce cubs only at 3-4 years of age after acquiring permanent home ranges. The sex ratio is equal at birth. If cubs survive to dispersal age, usually the tigress will produce the next litter after 2-2.5 years. If the cubs die in the interim, the tigress comes into oestrus almost immediately. In prey-rich habitats, the average cub production can be estimated at roughly 1 cub/breeding female/year (Karanth and Stith 1999). In such a productive population of 20 breeding females, roughly a third breed every year, adding about 20 new tigers to the population.

However, this high productivity of tigers is balanced by naturally high mortality rates. Tigers in all demographic stages die from a variety of causes. Male tigers that acquire new ranges try to kill the cubs of the former resident breeder. Other factors that cause mortalities among cubs include: starvation, floods, forest fires, other predators and human persecution. Hunting of tigresses also leads to indirect mortalities of dependent cubs (Sunquist 1981, Smith 1993, Karanth 2001). Juvenile tigers (1-2 years) die from starvation, hunting-related injuries and intra-specific aggression.

During dispersal phase, transient tigers move back and forth through larger ecological units, criss-crossing boundaries of breeder territories, nature reserves and even states or countries (Smith 1993). Such transient tigers suffer heavy attrition through starvation, intra-specific aggression and human persecution.

Based on data from Chitwan and Nagarahole, demographic models of tiger populations built by Kenny *et al.* (1995) and Karanth and Stith (1999) assumed the following approximate annual mortality rates in healthy tiger populations: cubs of both sexes 40%, juveniles of both sexes 10 %, transient males 35%, transient females 30%, breeder males 20% and breeder females 10%.

Factors that influence tiger population dynamics:

Karanth and Stith (1999) recently built a stochastic population model for tiger populations under different ecological scenarios. Their model of a productive (but insular) wild tiger population with a 'carrying capacity' of 24 breeding females, generated the following typical age-sex structure: 8 breeding males, 28 transients, 14 juveniles and 24 cubs. This population produces 24 cubs/year on an average, and, would be balanced by annual mortalities of the same magnitude. This model suggests that even relatively small wild tiger populations with only 12 breeding tigresses may be demographically viable. The model explains well how tiger populations could have survived the heavy pressure inflicted by hunters and poachers in the past. For example, between 1860-1960, approximately 93,000 tigers were legally killed for sport or bounties in parts of British India and some princely states (Rangarajan 1999).

The demographic model of Karanth and Stith (1999) indicates that rebounding tiger populations will quickly reach saturation densities, and remain relatively stable thereafter, because any further increase in reproduction rates is balanced by increase in mortality rates or dispersal. Therefore, in most productive tiger populations, there is potentially a 'doomed surplus', that perishes annually, without lowering the tiger population density (Karanth 2001).

The Karanth and Stith (1999) simulations also suggest that prey depletion (caused by human hunters or competition with livestock) reduces the numbers of breeding females and transients, as well as depresses cub survival rates. On the other hand, moderate levels of tiger poaching may simply remove a part of an existing annual surplus. In prey-rich habitats, a tigress may produce 3-4 litters or about 9-16 cubs during her reproductive tenure (Sunquist 1981, Karanth and Stith 1999), thereby producing a substantial 'surplus' of tigers. Consequently, human-induced prey depletion may be a far more serious threat to the viability of tiger populations than moderate levels of tiger poaching (Karanth and Stith 1999, Karanth 2001).

TIGER CONSERVATION IN THE INDIAN SUBCONTINENT

Conservation status of wild tiger populations

In historic times, tigers were found all the way from the Temperate Zone forests of the Russian Far East to the tropical forests of southwestern India. They ranged from Azerbaijan and Iraq on the West all way through the Indian subcontinent to parts of southern China, eastern Russia and Southeast Asia. Their range covered 30 present day countries, stretching over 70 degrees of latitude and 100 degrees of longitude on the earth's surface (Seidensticker *et al.* 1999, Karanth 2001).

Within the Indian subcontinent, tigers were present in a diverse array of habitats: Tropical Dry and Moist Deciduous Forests, Evergreen and Mangrove Forests, *terai* grasslands and Mixed Conifer-broadleaf Forests in the Himalayan foothills. Availability of ungulate prey, water and shade seem to determine their distribution (Sunquist *et al.* 1999, Chundawat *et al.* 1999, Karanth 2001). Tigers once overlapped with lions in a wide region stretching across northwestern India. Early human modifications of landscapes such as development of water resources, and extirpation of the more-easily hunted lions by human societies might have benefited tigers, allowing them to expand their range in drier regions of northwestern India by moving into newly-opened ecological niches (Karanth 2001).

Recent assessments (Wikramanayake *et al.* 1999) show that the current distributional range of tigers in the Indian subcontinent is around 350,000-400,000 sq. km (Fig. 1). Even within this reduced range, reproducing tiger populations are now restricted to a few better-protected reserves that may cover about 40,000 sq. km, or less than one percent of the tigers' historical range (Karanth 2001). The mountainous regions of the Himalaya, the dense evergreen forests of northeastern India as well as mangrove forests of India and Bangladesh, are inherently poor quality habitats for tigers. Lowland areas of Nepal and several Indian states have high quality habitat patches within the 50 or so protected areas that sporadically occur in a matrix of human-dominated landscapes.

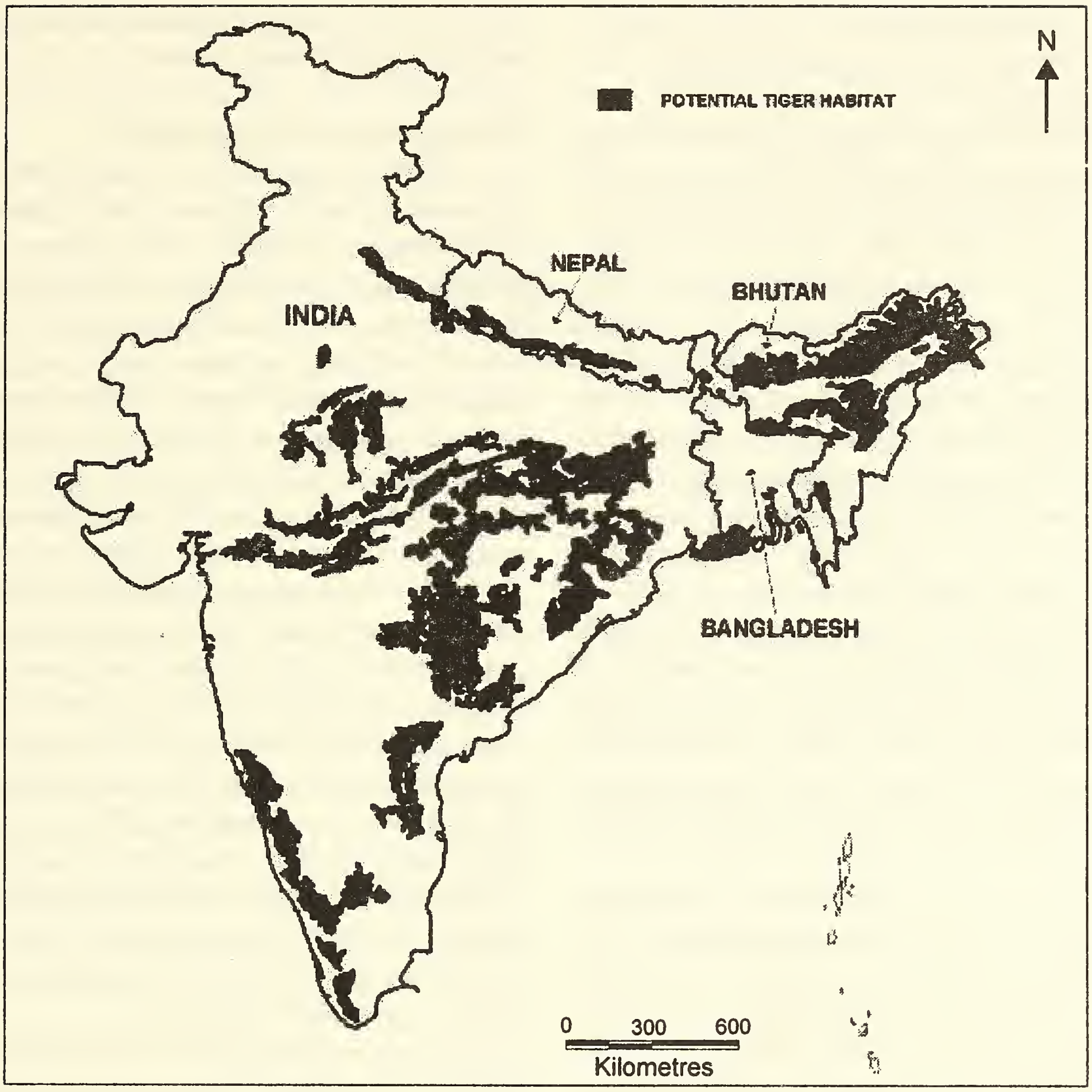
Perhaps over 90% of their range, local tiger populations cannot be sustained without periodic immigration from breeding populations in protected areas. In the overall landscape, such protected areas might be the only 'sources' from which tigers disperse and perish in the surrounding 'sinks' (Karanth 2001, Karanth and Chundawat 2002).

Furthermore, many of these 'source' tiger populations are under threat from prey depletion, tiger poaching, and, habitat degradation and fragmentation. These threats arise from a variety of factors linked to local rural uses as well as economic development projects (Karanth 2001). The potential erosion of genetic variability in wild tiger populations as a result of habitat fragmentation is considered to be a major threat by some workers (Tilson and Christie 1999). However, Caughley (1994) averred that the smallness of animal populations should be viewed as a consequence rather than a cause of animal extinctions.

All the above threats to tigers are generally recognised in scientific and popular literature (Seidensticker *et al.* 1999). Therefore, the essential challenge now lies in setting appropriate priorities in responding to these threats. Such priority setting must necessarily be based on an objective evaluation of past successes and failures in tiger conservation.

A brief history of tiger conservation

It is necessary to have a brief overview of the social context and history of tiger conservation in the Indian subcontinent before exploring current conservation issues. This outline is necessarily brief, and has to be read in the context



Source: ESRI 1992: Wikramanayake *et al.* 1999

Fig. 1: Potential tiger habitat in the Indian subcontinent

of more detailed historical analyses (Rangarajan 1999, 2001).

Throughout the 19th century and during the first half of the 20th, tigers were viewed as vermin to be eradicated by giving bounties to local hunters or as glamorous game animals to be exclusively hunted by elite 'sportsmen'. Both colonial rulers and native chieftains adhered to this view. Although some local cultures have traditionally revered tigers as deities (Jackson 1990, Karanth 2001), in practice such reverence made no difference to tigers as people persistently hunted tigers and their prey, and encroached on tiger habitat to convert it to farmland. However, in a few "game reserves" established for the sportsmen of the ruling classes who wielded substantial social power, "native poachers" were kept out. Consequently, tiger populations survived despite heavy pressure from elite hunters.

In the post-colonial period (after the 1950s) the first systematic attempts at tiger conservation were made under pressure from hunter-naturalists (Rangarajan 2001). These included the introduction of the first wildlife protection laws and establishment of "game reserves" all over India. However, due to the weakness of these efforts, tigers continued to be under pressure and were in decline into the 1960s. Only a few naturalists (Gee 1964, Daniel 1970) pleaded the case for more effective laws and protected areas for tigers. Around the same time, Schaller (1967) published the first scientific study of tigers, forcefully publicising their grim conservation status in the Indian subcontinent. Despite these early warnings, commercial tiger hunting by foreign tourists as well as "sport hunting" by the local elite prevailed, particularly in the forests of Central India (Sankhala 1978). During the late 1960s assessments by Sankhala (1978) and a questionnaire survey by Daniel (1970), both re-confirmed the tiger's precarious status in India, suggesting (without much evidence) that tiger numbers in India could be lower than 2000 animals. Such concerns led to effective lobbying and support from international conservation agencies (mainly IUCN and the World Wildlife Fund) that resulted in the Governments of India and Nepal initiating stronger tiger conservation measures (Jackson 1990).

At the core of these fresh conservation initiatives were the greatly strengthened wildlife protection laws, special protected reserves for tigers and increased funding for protective infrastructures (Panwar 1987, Karanth 2001). The criticisms that such tiger recovery measures were based on a top-down perception of conservation and did not sufficiently empower or involve local people in tiger conservation (Saberwal 1997, Rangarajan 2001) are valid. However, it is equally true that in most protected areas where these "top-down" conservation measures were implemented, significant recovery of tiger populations, prey base and habitats was observed (Karanth *et al.* 1999, Karanth 2001). These recoveries resulted from measures that met the ecological needs of tigers by reducing pressures of incompatible uses of tiger habitats by local people as well as by forestry departments. Had these unpopular protective measures not been put in place, it is very likely that tigers would have been extirpated from even these protected areas, as indeed they were from forests outside them.

Shifting conservation paradigms

Unfortunately, the tiger population recoveries in the 1970s and '80s in the Indian subcontinent were not documented using rigorous science (Karanth *et al.* 2003). As a result, the conservation community at large did not draw correct inferences from these large-scale conservation "experiments". Consequently, the proposed alternative of a more "bottom-up" conservation policy (Kothari *et al.* 1995) downplays the importance of preservationist measures. Instead it emphasises "sustainable use". This alternative conservation paradigm appears to advocate "human-tiger coexistence" and multiple use of even designated priority tiger conservation areas (Kothari *et al.* 1995, Saberwal 1997). Although tigers did "coexist" with subsistence-level human use of their habitats in the past, they lost ground steadily as a result of the ensuing conflict. The tiger's distributional range shrank by more than 95 percent in the process, within a few centuries. How such coexistence can now become beneficial to tigers again remains undemonstrated.

Tigers are landscape animals that typically live at low densities. The area needed to support a wild tiger population with 25 breeding females may range from 500 to 5,000 sq. km, depending on prey density and other habitat parameters. Being large-bodied carnivores, tigers readily kill livestock and occasionally, humans. When tigers lose their natural fear of humans, they can become persistent man-eaters (McDougal 1987, Karanth 2001). Usually, increased human use of tiger habitat depresses densities of principal ungulate prey (Karanth *et al.* 1999) through hunting, competition with livestock, and over-harvest of vegetation. Consequently, productive tiger populations cannot "coexist" with activities such as agriculture, livestock grazing, minor forest product collection and intensive logging, without serious human - tiger conflict. In the long run, such conflicts inevitably lead to the extirpation of tigers from areas of intensive human use.

Therefore, the assertion that local involvement in resource extraction from tiger habitats, together with the political empowerment of 'local people' are sufficient conditions to recover tiger populations, rests on no solid evidence either in ecological theory or in conservation experience. While there could be arguments over 'who' should manage tiger reserves, there is no doubt that such special reserves are needed, and, 'someone' has to enforce the preservationist measures necessary to maintain and perpetuate them.

Currently, as a result of increasing human and livestock densities, higher rates of forest-product harvests and hunting (all linked to growing commercial markets), wild tiger populations are declining. Intensification of human use of tiger habitats, and economic development projects, both now present major threats to their ultimate survival (Karanth 2001).

Scientific knowledge of tiger biology as well as our empirical knowledge of past conservation practices (what works and what does not) reviewed above, clearly show that reducing human pressures on tiger reserves and buffering them against incompatible land use practices outside, and extending and increasing connectivity among these reserves, are the best ways to recover and sustain wild tiger populations.

A renewed commitment to such effective protected tiger reserves, under a new conservation paradigm of maintaining 'sustainable landscapes' overall, rather than implementing 'sustainable use' practices everywhere, seems to be the most fundamental paradigm change necessary to save tigers in this century and beyond. However, conservationists appear to be often distracted from this central task by a variety of 'surrogate tiger conservation activities'.

Surrogate tiger conservation activities

Because the practical measures necessary to recover wild tiger populations are socially and politically complex and difficult to implement in almost any specific local context, conservationists often escape from them by taking up 'surrogate tiger conservation activities'. As a result, currently, a substantial amount of goodwill, concern, effort and financial resources meant to support tiger conservation are being misdirected at implementing such surrogate solutions. While some of these activities simply divert scarce resources and energy away from more immediate needs, others adversely affect tiger conservation in a more direct manner.

One example of surrogate tiger conservation is the disproportionate attention paid to initiatives that involve captive breeding, assisted reproduction and reintroduction of tigers, ostensibly for augmenting wild populations or maintaining genetic viability or for promoting animal welfare. However, this approach is fundamentally flawed for reasons explained in the following paragraphs.

Wild tiger populations have been extirpated through demographic causes (increased mortality, decreased reproduction) that are driven by over-hunting, prey depletion and habitat loss. Reintroductions serve no purpose in replenishing wild populations because the introduced tigers will also be eliminated by the same causes. As to the issue of genetic viability, leading conservation geneticists and population ecologists (Lande 1988, Caughley 1994) have argued that smallness of wild populations is most likely an effect of demographic factors and not their cause. Even if infusion of new genes into an isolated tiger population is scientifically demonstrated as a real need, it is more efficient and practical to capture and translocate dispersal-age individuals between wild tiger populations, rather than reintroduce captive animals that have to be reared and trained at great cost.

Given what we know about the social organisation of tigers, even in the unlikely event that an introduced animal establishes a range and breeds, such an introduction will inevitably involve the killing or eviction of an existing resident breeder. It will also have the same disruptive influence that the natural turnover of resident breeders in a population involves. Because the number and sizes of tigers an area can support is limited by prey density, there will be no net population gain even after a successful introduction. Even in a rare (and expensive) case of successful reintroduction, the new animal simply replaces some other less fortunate individual in the population. Therefore, tiger reintroduction can neither be logically justified as a population augmentation tool, nor even be defended as an animal welfare measure.

On the other hand, if the reintroduced tiger fails to establish a home range, as is more likely, there are high probabilities of the cat turning into a 'problem animal' that kills livestock or even humans. Such an event will further aggravate the antipathy local people already feel towards tigers and exclusive reserves that protect them, thus making the job of genuine tiger conservationists even more difficult than it already is.

Another example of surrogate conservation involves diversion of tiger conservation monies to other worthy social objectives like providing schools, hospitals and other services to people living around tiger habitats. Such activities indeed should be funded, but out of the much larger pool of money earmarked for developmental and social causes. Given that resources earmarked for tiger conservation are meagre, and the demonstrated immediate needs are for improved protection, habitat consolidation, conservation monitoring and conservation education — all currently under-funded activities — diversion of conservation funds to meet social objectives that have no immediate impact on wild tigers is also a form of surrogate tiger conservation.

An extreme example of the above approach are the current "eco-development projects" of various kinds being implemented with the assistance of the World Bank-GEF combine and other multilateral aid agencies, and with enthusiastic support from a large number of Indian officials and conservationists. These projects have diverted huge amounts of money, energy and attention away from the core issue of tiger protection towards largely wasteful "developmental" activities leading to further deterioration of tiger protection (Karanth 2002).

Another oft-promoted surrogate activity is 'eco-tourism', a term often misapplied to the expensive corporate sponsored form of wildlife tourism practised in India. It is true that well-managed tourism involving charismatic animals like tigers can generate substantial revenues for the reserves and help protect tigers directly. Such schemes can also potentially generate incomes and revenues for the local people around the tiger reserves, thus engendering additional public support for tigers. Rarely, such projects can also lead to land use changes outside the reserve that are favourable to tigers (Dinerstein *et al.* 1999). However, unfortunately, the high-revenue tiger tourism practised in India is singularly devoid of any of these positive features. It simply constitutes a large net drain on the park budgets and engenders mostly apathy or even hostility among local residents whose access to and use of tiger habitats has been curtailed to meet tiger conservation needs. Therefore, in the Indian subcontinent, despite its vast potential, eco-tourism has been turned into another surrogate tiger conservation activity that confers little benefit to the target species.

Beyond the pugmark census: ecological monitoring of tigers

We need to monitor tiger populations for three fundamental reasons. Firstly, to objectively evaluate the success or failure of past conservation interventions, so as to react adaptively to solve problems. A second major goal is to establish benchmark data that can serve as a basis for future management. A third overarching goal of tiger monitoring is to improve our basic understanding of tiger ecology and behavior to develop a body of empirical and theoretical knowledge that can potentially improve our predictive capacity to deal with new situations (Karanth *et al.* 2002).

At this point, given the critical status of tigers and the substantial investments made in their conservation, wildlife managers and conservation agencies need clear and reliable answers to some basic questions given below (Karanth *et al.* 2002, Karanth and Chundawat 2002), without which they cannot even begin to evaluate the success or failure of tiger conservation:

1. What is the extent and range occupied by different individual tiger populations?
2. Where are individual tiger populations increasing their range, and, where are these ranges fragmenting or shrinking?
3. Within the distributional range of tigers, what is the proportion of the area occupied by productive, breeding populations?
4. In important individual tiger reserves, what are the tiger population trends? Are tiger populations in such reserves holding steady, declining or increasing?

The traditional approach to answering such questions has been based on attempts to obtain total counts of wild tigers all over the country through 'pugmark censuses' (Choudhury 1970, 1972). Such 'census-based' approaches have major biological and statistical weaknesses (Karanth 1987, 1999, Karanth and Chundawat 2002, Karanth *et al.* 2003). Therefore, the need to employ more reliable 'population sampling-based' methods tailored to suit a variety of practical contexts is being increasingly realised (Anon. 1997, Karanth *et al.* 2002)

During the past 35 years, our knowledge of tiger ecology has advanced significantly as a result of several scientific studies. During the same period, methodologies for assessing wildlife population parameters have also developed substantially. In particular, two conceptual approaches to population sampling, Distance Sampling and Capture-Recapture Sampling, have advanced particularly rapidly (Thompson *et al.* 1998, Williams *et al.* 2002). Such methods now offer powerful tools for ecological monitoring of tigers and other wildlife in India. The type of monitoring feasible in each specific context can be determined by considering the potential methods in relation to available resources and local conditions.

The following guidelines from Karanth *et al.* (2002) may be useful in choosing a monitoring method appropriate to any specific local context:

1. It is almost impossible to estimate absolute or even relative densities of tigers or prey if trained manpower, equipment and other resources are extremely limited, and, large regions, states or countries have to be covered. Since most of the distributional range of tigers in the Indian subcontinent typifies such conditions, one can only attempt sample surveys of presence of tigers and prey species to estimate and map their distribution at this large landscape scale.
2. Where adequately trained personnel are available, measuring the relative density of tigers from sample surveys of encounter rates with tiger tracks or scats or the relative densities of prey species from pellet or dung counts are options (Karanth and Kumar 2002). It is likely that such index-based surveys are feasible only in some individual reserves.
3. If special equipment, trained personnel and other resources are available, absolute densities of prey species can be estimated from line transects using distance sampling methods (Buckland *et al.* 1993, 2001). Even absolute densities of tigers can be estimated using photographic capture-recapture sampling from camera trap surveys (Karanth and Nichols 1998, 2002a). Such advanced methods are likely to be practical only in a few priority tiger reserves or study sites.

If there is a mismatch between available resources and the goals that tiger managers hope to achieve, failure of monitoring is almost certain. The goal (1) of monitoring tiger or prey spatial distribution is a critically important first step in implementing any landscape level conservation programmes. Gradually, over the years, one can build up the capacity and resources to try to meet objectives (2) and (3) in priority conservation areas.

I emphasise that if the goal is to *reliably* estimate parameters such as tiger densities, survival and recruitment rates, there is no escape from implementing advanced population estimation methods. However, these methods can be employed only where necessary skills and resources are available. They cannot be applied for routine population surveys over large regions. However, the two most critical needs of tiger monitoring in the Indian subcontinent, mapping spatial distributions over large regions and determining population trends in specific reserves through indices, are widely attainable goals using relatively simple methods (Karanth and Nichols 2002b).

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BEAR CONSERVATION IN INDIA

(*With four text-figures*)

A.J.T. Johnsingh[1]

Key words: Himalaya, northeastern India, *Ursus arctos isabellinus*, *U. thibetanus*, *Helarctos malayanus*, *Melursus ursinus*, Transfrontier Reserve, poaching, shifting cultivation

Of the eight bear species currently existing in the world, four are found in India: brown bear *Ursus arctos isabellinus*, Asiatic black bear *U. thibetanus*, sun bear *Helarctos malayanus* and sloth bear *Melursus ursinus*. The abundance of each species in India is determined by habitat type, its location within the global distributional range of the species, its biology, the quantum and continuity of habitat available, and the anthropogenic pressures it faces. All species are in Schedule-I of the Indian Wildlife (Protection) Act 1972, the highest legal protection status.

India marks the southeastern end of the brown bear's distribution range; the black bear in India occupies a large portion of the southwestern part of the species' range, sun bear the western end, and sloth bear most of the species' range. Populations at the periphery of the range of the species are usually more exposed to pressures, and have greater chances of going extinct.

The habitat available to the largely herbivorous, hibernation-dependent brown bear in the Trans- and Greater Himalaya is probably limited to *c.* 10,000 sq. km, and is disturbed by anthropogenic pressures such as grazing and medicinal plant collection. There are about 23 protected areas in the range of the brown bear, within which there are around 300 animals. The omnivorous black bear has a vast forested habitat in the Outer and Greater Himalaya and northeastern India (*c.* 300,000 sq. km), with at least 56 protected areas and a minimum of 3,000 animals. Black bears in the higher reaches of the Greater Himalayan ranges hibernate, while those in the Outer Himalaya and northeastern India, where they range as low as 500 m, do not. Although disturbed, black bear habitat in the Himalaya is still continuous and productive as a result of orchards and croplands. Poaching for gall bladder, fat, meat and skin is a threat to the species. The sun bear is extremely rare in India, and is confined to the forests along the Myanmar border. Hunting, shifting cultivation and capture of young for trade, after killing the mother, are the threats across the species' range. The myrmecophagous sloth bear still has a vast habitat (250,000 sq. km), harbouring a minimum of 10,000 bears. Yet it is threatened by habitat degradation and fragmentation, poaching for gall bladder, and capture of young to be trained as performing bears.

Long-term conservation of the brown bear in the Himalaya is possible only with: (i) cessation of hostilities between India and Pakistan, leading to the formation of a Transfrontier Reserve protecting the bear habitat, (ii) a total ban on the capture of young for bear baiting with dogs, and (iii) ensuring that the protected areas are not unduly disturbed between May and October. Protection against poaching and capture of cubs is a must for the conservation of the black bear and the sloth bear. Weaning the people in the former range of the sun bear from shifting cultivation, and protection from poaching, may revive the habitat and population of the sun bear.

INTRODUCTION

India is unique in having four of the eight extant species of bear. They are the brown bear *Ursus arctos isabellinus*, the Asiatic black bear *U. thibetanus*, the sun bear *Helarctos malayanus*, and the sloth bear *Melursus ursinus*. This uniqueness is due to India's geographic location at the junction of the Palaearctic and Indo-Malayan biogeographic zones, which enabled Palaearctic species (brown and black bear) and an Indo-Malayan species (sun bear) to range into the Indian subcontinent. The sloth bear probably

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radiated from the ancestral stock of brown bear during the mid-Pliocene (Kurten 1968), and evolved within the Indian subtropical region.

The brown bear in Asia is the same species as the North American grizzly, but the populations inhabiting the Himalaya and the northern mountain ranges of the Tien Shan and Altai have been ascribed to a separate subspecies. This is due to its smaller average size, generally whitish claws, and the guard hairs often being pale at the tip. The Asiatic black bear is considered the ecological equivalent of the American black bear (*Ursus americanus*) in terms of body form and habits (Roberts 1997, Schaller 1977). The sun bear is the smallest of the eight bear species, and the only one inhabiting lowland tropical rainforests throughout much of southeast Asia (Servheen 1999a).

BEAR HABITATS IN INDIA

Mainland India has been categorised into nine biogeographical zones (Rodgers and Panwar 1988), eight of which are important for bears. The vegetation descriptions given below are from Champion and Seth (1968).

The northernmost Palaearctic zone, the Trans-Himalaya, lies north of the main Himalayan range in Jammu and Kashmir, and within the dry inner Himalayan valleys of Himachal Pradesh. Vegetation here consists primarily of dry steppe and alpine scrub, dominated by xerophytic plants that reflect the extremely dry and cold climatic conditions. Typical throughout the region are the streamside *Salix*, *Populus* and *Hippophae* associations, and *Juniperus* and *Betula* woodlands on mountain slopes, primarily in Himachal Pradesh. The brown bear occasionally visits these areas.

The Himalayan Zone includes the mountains of southwest Jammu and Kashmir, Himachal Pradesh, Uttaranchal, Sikkim, West Bengal and Arunachal Pradesh. It encompasses a complex topography, and a mixture of vegetation formations with distinctive altitudinal zonation. Dominant forest types in the northwestern Himalaya include the chir pine (*Pinus roxburghii)* forests in the Siwalik hills; subtropical evergreen forests up to 1,000 m above msl, characterised by *Persea odoratissima*, *Olea glandulifera* and *Syzygium operculatum*; moist temperate oak (e.g. *Quercus incana)* and conifer (*P. roxburghii*) mixed formations; and mixed conifer and conifer-deciduous associations with *Abies*, *Cedrus*, *Taxus*, *Acer* and *Betula*. Between 2,900 and 3,500 m, dry temperate forests dominated by *Pinus wallichiana* replace the moist temperate vegetation. Beyond this, subalpine patches of *Betula* and *Juniperus* grade into shrublands of *Berberis*, *Lonicera* and *Rhododendron*, and finally scrub and herb up to *c*. 5,000 m.

The central and eastern section of the Himalayan zone is more strongly affected by the monsoon rains, and the vegetation is both denser and richer. The tropical semi-evergreen forests below 1,000 m above msl, are characterised by *Phoebe hainesiana, P. lanceolata, Terminalia myriocarpa, Bischofia javanica* and *Schima wallichii.* Above this, are broad-leaved forests up to 2,000 m, with various *Quercus* species. Sub-alpine forests, beginning at elevations >3000 m, are dominated by *Pinus*, *Betula*, *Rhododendron* and *Acer* species up to 4,500 m, where they give way to sparse scrub extending as high as 5,500 m on southern aspects. The higher altitudes (>3,000 m) of these habitats are used by brown bear in Sikkim and middle and lower altitudes (800-2,500 m) by black bear. Below 1,000 m, black bear and sloth bear habitats may overlap.

The North-East India Zone includes the Brahmaputra valley (*Shorea assamica*, *Cephalanthus cetrandra*, *Glochidion hirsutum* and *Phragmites karka*) and Assam hills (*Shorea assamica*, *Dipterocarpus macrocarpus*, *Amoora wallichii*, *Mesua ferrea* and *Dendrocalamus hamiltonii*). These areas include the habitat of the black bear, sloth bear and sun bear.

The semi-arid tracts of Gujarat (*Tectona grandis*, *Capparis decidua*, *Carissa carandas* and

Zizyphus nummularia), Upper and Lower Gangetic plain (*Shorea robusta*, *Syzygium cumini*, *Zizyphus mauritiana*, *Glycosmis pentaphylla*), Deccan peninsula (*Tectona grandis*, *Madhuca latifolia*, *Diospyros melanoxylon*, *Z. mauritiana* and *Cassia fistula*), and the Western Ghats (*Artocarpus heterophylla*, *Mangifera indica*, *Cullenia excelsa*, *Macaranga peltata*, *Hopea parviflora*, *Mesua ferrea*, *Ochlandra travancorica*, *Buchanania lanzan*, *Phoenix humilis*, *Z. mauritiana* and *Z. oenoplia*) are used only by the sloth bear.

STATUS OF BEAR SPECIES IN THE INDIAN SUBCONTINENT

Brown bear

The southern limit of the brown bear in Asia is the Himalaya, where it is largely confined to rolling uplands and alpine meadows above the timberline, thus ecologically separated from the forest-dwelling black bear (Schaller 1977; Fig. 1). The brown bear was once abundant in the Himalaya, with Kinloch (1892) having seen 28 in one day. The brown bear has become rare in Pakistan, and summarising the survey results of Choudhry and Farooq (1995), T.J. Roberts (pers. comm.) estimates about 40-50 brown bears in Pakistan. Although Gee (1967b) reported the shooting of a brown bear in Bhutan, there is no report of brown bear in Bhutan in recent years. Brown bear occurs in Upper Mustang in Nepal (Anon. 1994a).

Sathyakumar (1999) gives an excellent review of the occurrence of brown bear in India where the populations are largely confined to the western and northwestern Himalayan ranges in

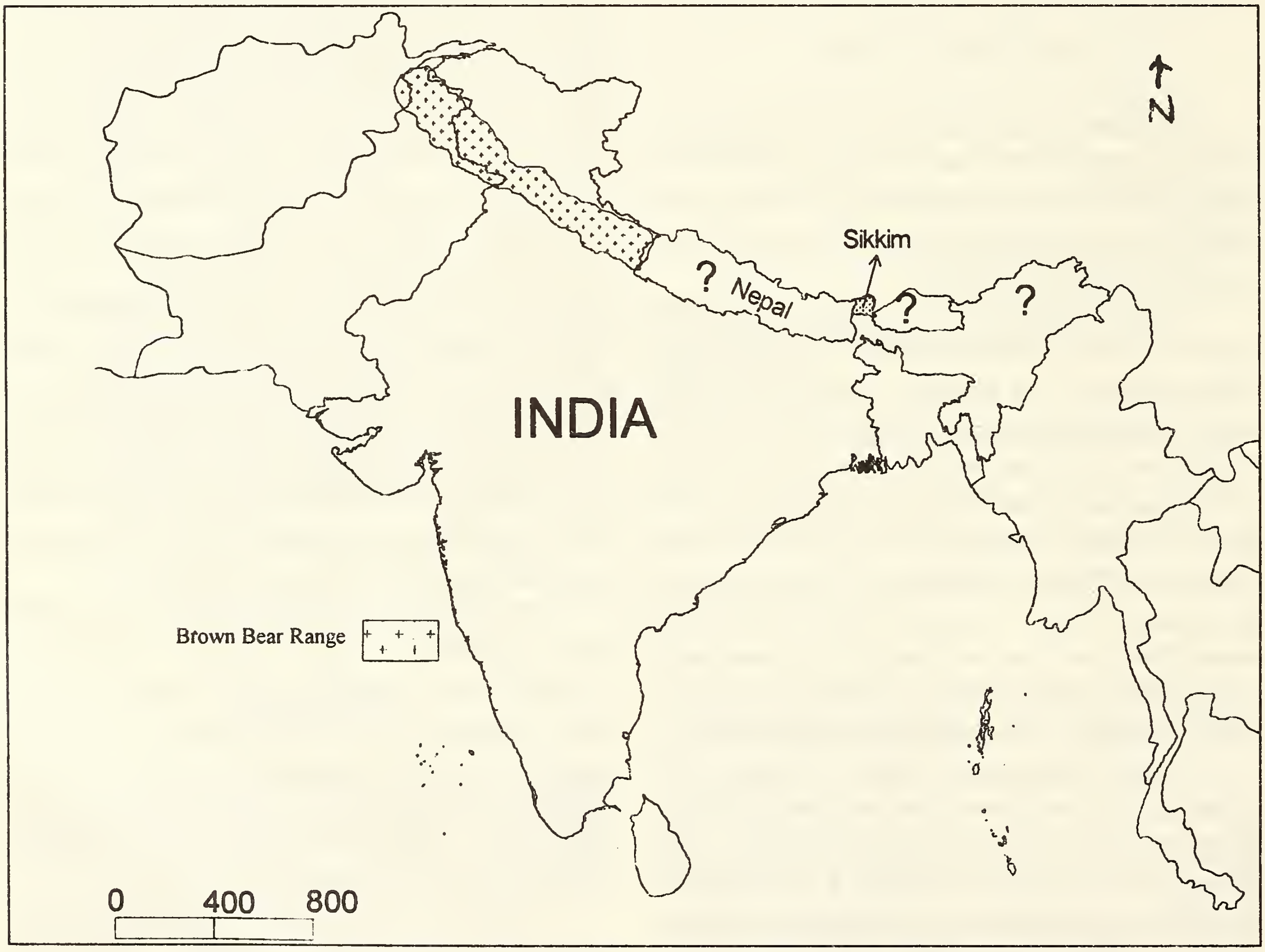

Fig. 1: Brown bear range in the Himalaya (After Roberts 1997, Sathyakumar 1999)

the states of Jammu and Kashmir, Himachal Pradesh and Uttaranchal (Fig. 1). A small population, possibly continuous with the population in Tibet, occurs in Sikkim. The subspecies in Tibet has been identified as *Ursinus arctos pruinosus* (Schaller 1977, Mallon 1985), which may range into Sikkim and Nepal. Brown bears may range into the alpine regions of the Eastern Himalaya (Arunachal Pradesh), but no confirmed reports are available. There are possibly around 300 brown bears in India.

Black bear

In Asia, the distribution range of black bear from west to east, once extended through Iran, Afghanistan, north and northwestern Pakistan, the higher altitudes of Nepal, Bhutan and the Indian Himalaya, forested tracts of Myanmar, Thailand, Indo-China, southern and northeastern China, Taiwan, Far-eastern Russia and Japan (Roberts 1997, Schaller 1977, Servheen 1999a; Fig. 2). The habitat available to the black bear in the Outer and Greater Himalaya and northeast India could be about 300,000 sq. km. Although disturbed, the black bear habitat in the Himalaya is still relatively continuous and productive, as a result of orchards and croplands. In India, black bears have been reported to occur in 56 protected areas covering 18,340 sq. km in the states of Jammu and Kashmir, Himachal Pradesh, Uttaranchal, Sikkim, West Bengal, Arunachal Pradesh, Meghalaya, Mizoram and Tripura. Protected areas with black bears range in size from 1 sq. km to 2,237 sq. km (an average of 330 sq. km). However, information about black bear status is scanty in most areas, and there have been no reports from Manipur and Nagaland (Sathyakumar 1999). Choudhury (1997) reports that black bears are found in the hills of northeast India, with a few records from the plains. However, during a four-month study on elephant-human conflict in Garo hills in Meghalaya in 1995, Christy Williams (pers.

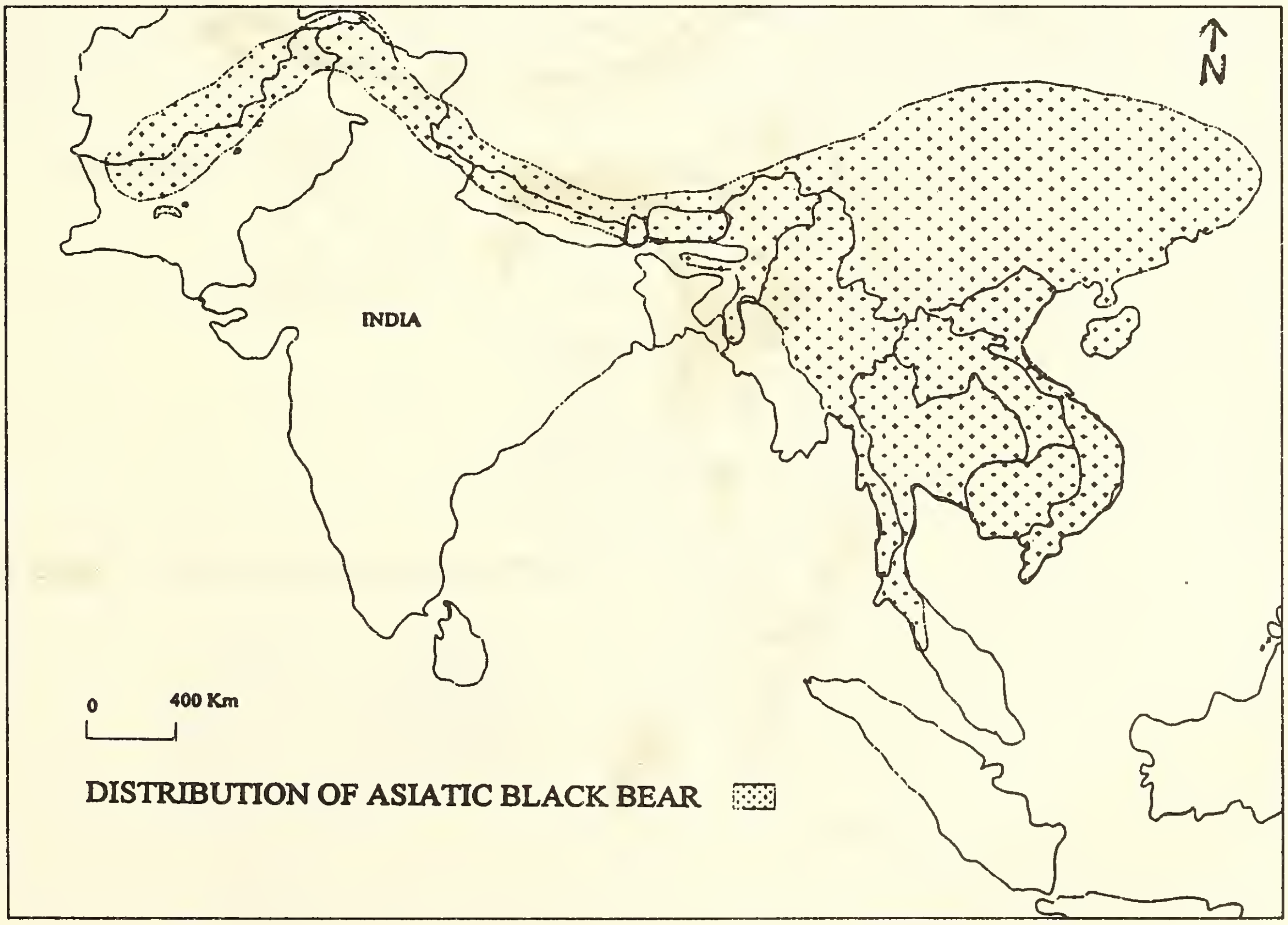

Fig. 2: Distribution of Asiatic black bear in the southern part of its range (After Servheen *et al.* 1999b)

comm.) did not find any evidence of black bear. Similarly, T.R. Shankar Raman (pers. comm.) did not find any evidence of black bear during his 120 days of fieldwork in Dampa Tiger Reserve in Mizoram in 1994-1995. There are probably at least 3,000 black bears in India.

Sloth bear

The sloth bear is restricted to the Indian subcontinent: India, Sri Lanka, Nepal and Bangladesh. In all these countries, sloth bear distribution has shrunk and become patchy over the decades (Fig. 3). In Sri Lanka, a population of about 400 is found largely in the northern and eastern lowlands (Santiapillai and Santiapillai 1990). In Nepal, sloth bears are largely confined to the lowland *terai* protected areas such as Chitwan–Parsa and Bardia. Chitwan has the highest density, and density in Bardia is reported to be lower, as it does not have extensive alluvial grasslands like Chitwan. East of Chitwan, the range extends just short of Kosi Tappu Wildlife Reserve. No evidence of sloth bear was seen in Royal Suklaphanta Wildlife Reserve in 1993-94 and sloth bear numbers in Nepal are probably less than 500 (Garshelis *et al.* 1999). Once sloth bear occurred in Suklaphanta (Spillet and Tamang 1967); Cliff Rice (*pers. comm.*) took a picture of a bear feeding in a burnt *terai* grassland in December 1976. It is difficult to understand why the sloth bear has

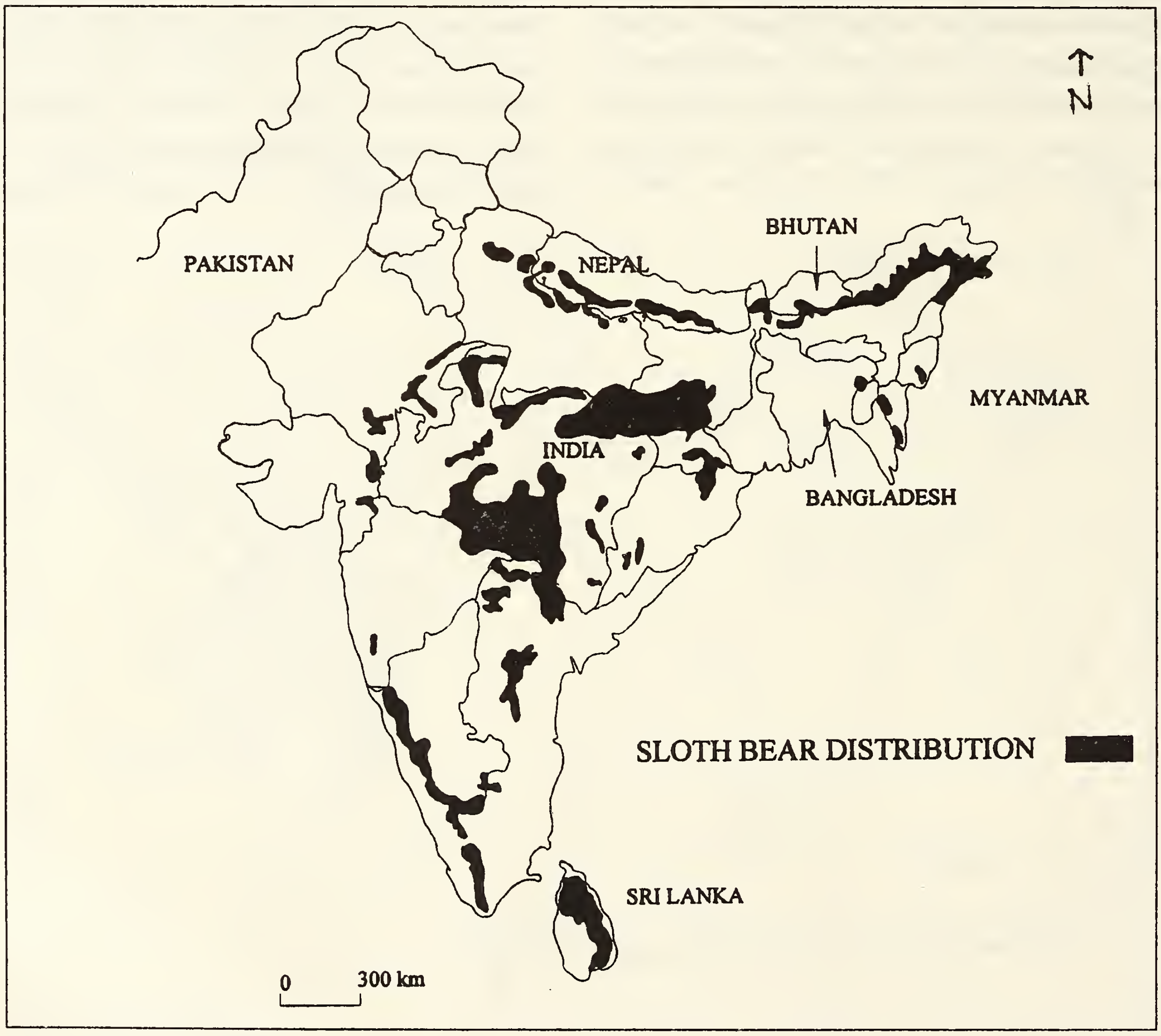

Fig. 3: Sloth bear distribution in the Indian subcontinent
(After Yoganand, K., C.G. Rice and A.J.T. Johnsingh)

become extinct in Suklaphanta, which has extensive alluvial grasslands supporting the best population (*c.* 2,000 of the total 5,000) of swamp deer *Cervus duvaucelii duvaucelii* (Gopal 1995). A recent report by the WWF-Nepal Program (2002), however, indicates that "there may be only a few individuals in and around the Reserve." Sloth bears may still occur in the remnant, Mixed Evergreen Forests of Bangladesh. One sighting of a sloth bear with a cub in Dampa Tiger Reserve in December 1994 (T.R. Shankar Raman, pers. comm.), and evidence in Balpakram National Park (Christy Williams, pers. comm.) have been reported.

In India, a population of about 10,000 sloth bears still occurs, widely distributed over a habitat of 250,000 sq. km, although the habitat is discontinuous and highly disturbed in most places. The sloth bear ranges throughout peninsular India, up north to the foothills of the Himalaya, inhabiting most low altitude, non-arid areas where forest cover still remains. The forests of Western Ghats and the Central Indian Highlands are currently the two strongholds of the sloth bear (Yoganand *et al.*, unpubl.).

Sun bear

Servheen (1999b) summarises the historic range and current distribution of the sun bear. Of interest are the historic records of sun bears in places like eastern Tibet and Sichuan, China (Lydekker 1906), Manipur and Assam (Higgins 1932) and the upper Chindwin district in present day Myanmar (Wroughton 1916), places where the species is now extinct. The sun bear is now found in Southeast Asia from Myanmar eastward through Thailand, Indo-China and Malaysia. It is also found on the islands of Sumatra and Borneo. Although Ullas Karanth (pers. comm.) has obtained a camera trap photograph of the species, in Namdapha Tiger Reserve in Arunachal Pradesh (Fig. 4), in the late 1990s, its occurrence in India is very rare, and probably confined to the forests along the India-Myanmar border.

BEHAVIOURAL ECOLOGY OF BEARS RELEVANT FOR CONSERVATION

The review on brown bear is largely based on Roberts (1997) and Schaller (1977). The brown bear inhabits high alpine mountain slopes and

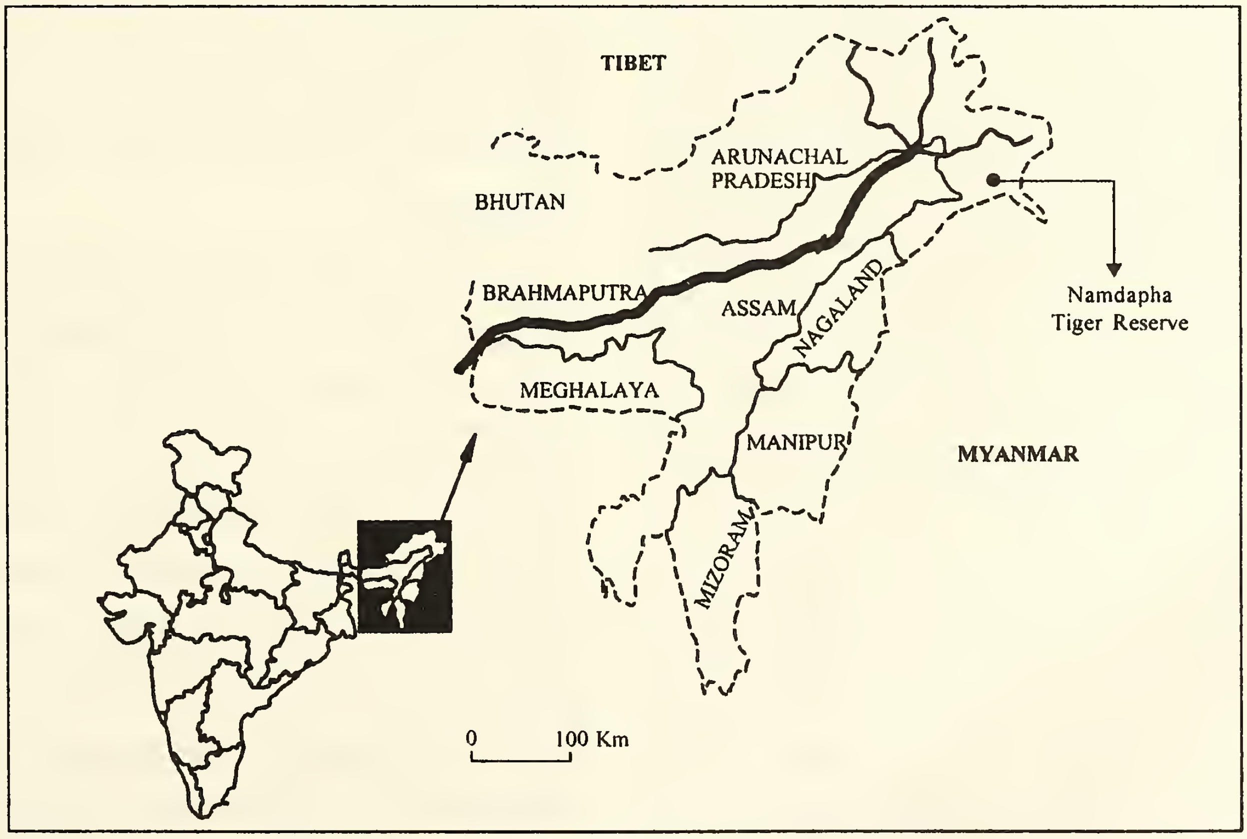

Fig. 4: Range (south of Brahmaputra) of sun bear in India

valleys above the tree line, from about 3,000 m to 5,000 m. It generally avoids coniferous forests, although it will descend to cultivated valleys in late summer to raid crops and trees in fruit. It is shy and fearful of man, avoiding upland valleys occupied by nomadic herders. It has rather poor eyesight and hearing, but an extremely acute sense of smell. It locates by smell and even digs out high altitude *Alticola* (voles) from their burrows. The brown bear is skilled in catching fish, and alpine torrents on the Deosai in Pakistan that have snow trout (*Dipticus maculatus*) are favourite hunting grounds for the bears. However, analysis of bear scats and three years of research in the Deosai have shown that 90% of their diet is made up of vegetable matter, comprising various sedges, grasses and especially starchy rhizomes and bulbs of *Carex* (sedges), *Juncus* (rushes) and *Eremurus* (foxtail lilies). Only 2 of 70 faecal samples collected contained rodent or fish bones (Anon. 1994b). Occasionally, an individual learns to kill domestic stock, and such animals become notorious, killing up to 30 sheep and goats in one night if they get into a penned enclosure (Kruuk 1972). In early summer, brown bears dig assiduously on grassy slopes in search of succulent rhizomes and tubers, and turn over rocks for insects and crustacea lurking beneath. They are strongly attracted to carrion and have been observed feeding on the remains of ibex (*Capra ibex sibirica*), which commonly get killed in winter avalanches. In Deosai, the radio collared bears frequently foraged over a distance of 5 km during the course of one day. Usually they forage only for a few hours early in the morning and in the evening, but when human disturbance is high, they forage only at night.

Mating in brown bear takes place from late June to end July, and there is delayed implantation of the fertilised ova. The bears go into hibernation in October. During hibernation, they frequently emerge above ground in warmer weather. Usually two cubs are produced during hibernation, and they remain dependent on their mother for at least two years, often accompanying her for up to three years. Females generally start breeding at the age of five and thereafter breed once in three years. Adult males, which can be cannibalistic, are avoided by a female with cubs.

Although the Asiatic black bear is an omnivore, a major part of its diet is made up of fruits, which often need to be collected from trees. As an adaptation for climbing, it has long claws on all paws. Other food items include leaf material, insects and other animal matter in smaller proportions. In areas where the bears hibernate, their active period is limited to about six to eight months. During the active period, feeding forms the major activity. The study of feeding of black bears in Dachigam National Park in Kashmir, from early May to early October, by Manjrekar (1989), showed that fleshy fruits (soft mast) like mulberry (*Morus alba*), cherry (*Prunus avium*), peach (*P. persica*) and raspberry (*Rubus niveus*), rich in sugar and carbohydrates, contributed significantly to the diet in summer. Schaller (1969) studied the feeding of black bears in Dachigam for a short period before their hibernation, from October 6 to 21. The three major food items during this period were the fruits of *Celtis australis*, walnut (*Juglans regia*) and acorn (*Quercus robur*), all fat rich. Manjrekar (1989) also found walnuts and acorns in the bears' autumn (pre-hibernation) diet.

Mating takes place between June and August. Bromley (1965) estimated hibernation to last between 128 and 170 days, starting from early November. In years of good crop, bears go into their lair earlier when fat deposition is adequate. The first to enter the dens are adult females with young. Other females, both barren and pregnant, are the next to den, and finally the males. During hibernation, bears move into lairs which are most often hollows at the base of a tree, otherwise in rock caves, under fallen logs or in ground dens that are dug by the bears sometimes even a few months before hibernation. Thermal stability, snow accumulation and lack of human disturbance are the factors that determine the selection of den sites (Hazumi and Maruyama 1983, 1986, Reid *et al.* 1991). There is evidence that the black bear does not always undergo either prolonged or deep hibernation, as it will occasionally emerge to forage even during the winter months (Roberts 1997). The emaciated males are the first to emerge, followed by the barren females and finally the females with cubs. Bears in the foothills of the Himalaya, northeast India, Myanmar, Thailand and Indo-China do not hibernate.

Usually two cubs are born between mid-January and mid-February, after a gestation of over six months (Bromley 1965, Nowak 1999). The cubs are weaned at two to two and a half years, and they become sexually mature at three or four years of age. Like all bears, the Asiatic black bear is usually solitary, and groups of three or more do not occur often, except as mother-cub associations, and as feeding associations especially during periods of clumped food resource availability. The tiger, leopard and wolf are the potential predators of black bear cubs in different parts of their range (Bromley 1965).

Based on the morphology of strong claws, jaws and long tongue, it can be concluded that the sun bear is adapted to climbing trees and extracting food such as insects, larvae or honey from cavities (Servheen 1999b). The sun bear is active at night, usually sleeping and sunbathing by day on a tree 2-7 m above the ground. Tree branches are broken or bent to form a nest and look-out post. The diet is omnivorous and includes figs and termites (*Prohamitermes mirabilis*) (Lekagul and McNeely 1988, Fredrickson 2001, Siew Te *et al.* 2001). Fredrickson (2001) observed the bears showing a preference for unburnt forests where the density of *P. mirabilis* was high. Birth may occur at any time of the year. Gestation period for nine pregnancies recorded from zoos varied between 95 and 240 days, evidently because of delayed fertilisation (Nowak 1999).

The sloth bear exhibits several adaptations to its subtropical and tropical habitat and diet. To suit the tropics, it has no underfur; however, it has a long coat that perhaps helps in defending it from insect bites and also perhaps to exaggerate its size to dissuade predators such as leopards (*Panthera pardus*) and dholes (*Cuon alpinus*) (Yoganand *et al.*, unpubl.). The monsoonal climate of the Indian subcontinent, and the resultant seasonality of resource availability, may have acted as selective pressures on the ancestor of the sloth bear to evolve to its present form, as suggested by Laurie and Seidensticker (1977). They also suggested that the sloth bear's morphological adaptations (like large powerful claws) and behavioural adaptations (like the capability to suck out insects), that were mostly driven by food hunting, are evolved for hard times when food is limited. Abundant fruit is limited to a few months, and there is also annual variability in production of fruits. The sloth bear has to subsist on other stable food resources like termites and ants that are more or less available year round. Although the sloth bear has diverged towards a diet composed largely of insects, it has retained the ability to use a variety of food in conformation with its omnivorous ancestry. Estimated sloth bear densities vary from 6 bears/100 sq. km for a dry habitat like Panna Tiger Reserve (Yoganand *et al.*, unpubl.) to 21 bears/100 sq. km in the much more productive Chitwan National Park, where ecological density during the dry season can go up as high as 70 bears/100 sq. km (Joshi 1996). The reported adult sex ratio is 1:1 (Laurie and Seidensticker 1977, Joshi *et al.* 1999, and Yoganand *et al.* unpubl.). Mating generally takes place between May and July, and the cubs are born between November and January. Litter size of two is most common (Laurie and Seidensticker 1977, Joshi 1996, Yoganand *et al.* unpubl.). Cubs are born either in a natural cave or in a den dug by the mother. Females seclude themselves in dens for 6-10 weeks, hardly coming out to forage, living on fat reserves and metabolic water during that period (Joshi 1996, Yoganand *et al.* unpubl.).

Cubs are frequently carried on their mother's back, until they are about six months of age (Laurie and Seidensticker 1977, Joshi 1996, Yoganand *et al.* unpubl.). This is the cubs' main defence against attacks by predators or other bears. Cubs stay with their mothers for one and a half or two and a half years, becoming independent just before the breeding season (Joshi 1996, Joshi *et al.* 1999). Thus, females breed at either two- or three-year intervals. The mother-young unit is the only permanent social grouping exhibited by the sloth bear (Eisenberg and Lockhart 1972, Joshi *et al.* 1999, Yoganand *et al.* unpubl.). They may also gather at places with abundant food, such as a dense patch of fruiting plants (Joshi 1996, Yoganand *et al.* unpubl.). Tigers attack, kill and feed on sloth bears occasionally (Joshi *et al.* 1999, Yoganand *et al.* unpubl.). Leopards, dholes and even jackals may harass the bears. The anti-predator strategy of the sloth bear is either to run away or respond with a spectacular charge and stand-up display. Its aggressive behaviour may be a consequence of not being able to rely on trees for escape, in a habitat that has predators capable of climbing trees, making it advantageous to live in fairly open habitat (K. Yoganand, pers. comm.). Sloth bears probably consider humans as predators. At close quarters they react to human presence as they would to a predator (Laurie and Seidensticker 1977, Yoganand, pers. comm.). They roar and run away, or roar and attack humans, before retreating. Bear attacks on humans are common throughout the range where bears and humans co-occur (Garshelis *et al.* 1999, Rajpurohit and Krausman 2000, Yoganand *et al.* unpubl.).

Conservation: problems and prospects

The survival of bear species in India is determined by their abundance, which in turn is determined by habitat type, location of the Indian range in the global distributional range of the species, quantum of habitat available, species' biology, and the anthropogenic pressures they face. Populations at the extreme or periphery ('edge') of the range of the species are usually sparse (Hengeveld and Haeck 1982) and have a greater chance of going extinct (Beddington *et al.* 1976, Lawton 1995). The sun bear occupies the western end of its range in India. Even in the past, it had a limited range in northeast India, confined to the hills south of the River Brahmaputra (Gee 1967a). The population was also possibly very small, since only 15 of the 1,389 bears killed in Assam between 1910 and 1917 by bounty hunters, were Malayan sun bears (Higgins 1932). Hunting, shifting cultivation or *jhuming*, and capture of young for trade by killing the mother, are the threats across the species' range. A forest subjected to *jhuming* gets re-colonised by primates including gibbon, if it is left fallow for a minimum period of 10 years, especially if it has connectivity with primary forests with a source population (Gupta and Kumar 1994). But so far no study has attempted to find out at what age a previously *jhumed* forest will become suitable for the arboreal sun bear. *Jhumed* forests with a 25 year fallow period have frugivorous and omnivorous bird species similar to forests left fallow for 100 years (Raman *et al.* 1998).

As the brown bear in India occurs in the southeastern end of the species' distributional range, it is also limited by the 'edge effect' described in the previous paragraph. The major decimating factors faced by brown bear are hunting [in the past, e.g., Kinloch (1892) killed 7 of the 28 bears he saw], and capture of cubs by local tribes like the Qalanders in Pakistan to train them for the cruel practice of bear baiting with dogs. A survey by Choudhry and Farooq (1995) found that Qalanders held no less than 215 brown bears in captivity, all trained for bear baiting with dogs. T.J. Roberts (pers. comm.) reports that between 35 and 80 brown bear cubs were sold each year to the Qalanders, and in the process of securing cubs, often twins, the mother is killed and frequently the weaker of the cubs also dies before reaching adulthood. It is possible that cubs from India may also be smuggled out for this nefarious entertainment on which a ban has been imposed by the Pakistan Government, supported by WWF-International. But the practice reportedly continues clandestinely, sustained by a few rich landowners. Continued border skirmishes between India and Pakistan would also affect the population occupying the border areas. In addition, the habitat of the brown bear is disturbed by grazing and medicinal plant collection.

The major problem faced by the black bear, which in India occupies a large portion of the southwestern part of the species' range, is poaching for its gall bladder, fat, meat and skin. While the first two are believed to be of medicinal value, the last is for trophy or ornamental purposes. Some black bear cubs may also be smuggled to Pakistan from India, as the survey by Choudhry and Farooq (1995) recorded about 300 black bears with Qalanders.

When compared with other range countries, the status of the sloth bear is relatively good in India, with India covering most of the species' range. Nevertheless, the sloth bear is threatened by habitat degradation and fragmentation in the dry tracts of its range, in the states of Bihar, Jharkhand, Chhattisgarh, Madhya Pradesh, Rajasthan, Gujarat, Maharashtra and Andhra Pradesh; also by poaching for gall bladder, bear-human conflicts, and stealing of cubs, by killing the mother, to be trained as performing bears (Yoganand *et al.* unpubl.).

Conservation of the brown bear would require the combined efforts of the Governments of India and Pakistan, by cessation of hostilities and creation of a Transfrontier Reserve covering the wildlife habitats across the Line of Control. In addition, all the protected areas in the range of the brown bear should be freed of disturbances from May to October, the crucial period for them to recover from the loss of physical condition due to denning, and to put on sufficient fat reserves for the next hibernation. Illegal trade in bear cubs should be stopped.

To help the sun bear re-occupy its former range in India, a strict control over poaching, and a long fallow period (> 25 years) for *jhumed* forests will be needed. Landscape planning in the bear range should include a mosaic of primary forests, > 25 year old *jhumed* forests, and corridors of *jhumed* forests of other age classes. Conservation of black bear and sloth bear would require stringent measures to control poaching and illegal trade in bear parts.

Given the magnitude of enormous biotic pressures and the low level of motivation of the officers and the staff assigned to the job of controlling poaching, the long-term future of brown bear and sun bear in India looks bleak. However, things have to change for the better, addressing all the conservation problems listed above, if the bear species, their habitats and other fascinating species inhabiting their habitat, are to be ensured a future in a populous country like India.

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KUDREMUKH NATIONAL PARK, KARNATAKA: A PROFILE AND A STRATEGY FOR THE FUTURE

(*With two plates*)

S.A. Hussain[1]

Key words: Kudremukh, langur, liontailed macaque, mining, Karnataka, Western Ghats

The 600 sq. km Kudremukh National Park straddles the Western Ghats adjoining the districts of Chikmagalore, Udupi and Dakshina Kannada. Rich deposits of magnetite and haematite in the Park has led to extraction of iron ore by the Kudremukh Iron Ore Company Limited (KIOCL) since 1980. The vegetation is of Western Tropical Evergreen Forest, with higher slopes and rolling hills having typical shola-grassland mosaic. Over 35 species of amphibians, 400+ species of birds and 38 species of mammals occur here. Flagship mammals include the liontailed macaque and a small isolated hitherto undescribed population of langurs, small in size, dark brown and shy, sharing the habitat of the liontailed macaque, the Malabar civet, and the brown palm civet. The flagship birds are the great pied hornbill, Nilgiri wood-pigeon, Wynaad laughingthrush, grey-breasted laughingthrush, blue-winged parakeet, grey-headed bulbul, white-bellied treepie and white-bellied blue-flycatcher. The KIOCL mining operations have caused some disturbance in the eastern part of the Park. KIOCL mining will close down soon and the infrastructure left behind needs to be put to good use without violating National Park rules. This paper suggests the appropriate course of action to address this issue.

INTRODUCTION

The Western Ghats forests comprising of Tungabhadra State Forest, the South Bhadra State Forest of the revenue district of Chikmagalur as well as the Naravi Reserve Forest and the Andar Reserve Forest of the revenue districts of Dakshina Kannada (DK) and Udupi (12°-16° N latitude) are now collectively designated as the Kudremukh National Park (KNP), notified on September 4, 1987 under Section 35(1) of the Wildlife Protection Act. It is under the control of Kudremukh Wildlife Division of the Karnataka State Forest Department. The Division looks after KNP, Someshwara and Mukambika Wildlife Sanctuaries in Udupi and DK districts. The Division Headquarters is located at Karkala Town. It has a Deputy Conservator of Forest (DCF) as the head, with three Assistant Conservators of Forest (ACF) located at the Headquarters, the Kudremukh mining township, and the Mukambika Wildlife Sanctuary, Kundapur Taluk, respectively. The KNP having a total area of about 600 sq. km comprises lowland as well as highland Tropical Evergreen Forests, shola-grassland-savanna and a mosaic of Mixed Semi-evergreen Forests and plantations in the peripheral areas (Plate 1, Fig. 1). The altitude ranges from 300 m in the lowlands to 1,892 m at the highest peak of Kudremukh. The average altitude of the highland hills is about 1,000 m. The area receives good rainfall during monsoon months (June-October; range = 1,778-6,350 mm, highest recorded was 10,000 mm, in 1984).

Precipitation and runoff regime is roughly defined at the crest of the ghat which also forms the western and eastern facies of the landscape. Thus, the watershed west and south of the divide is very steep, contributing to rapid runoff of short-span river systems that drain into the Arabian sea. The watershed east and north of the divide caters to river systems that meander through gentler slopes and gullies and flow eastward

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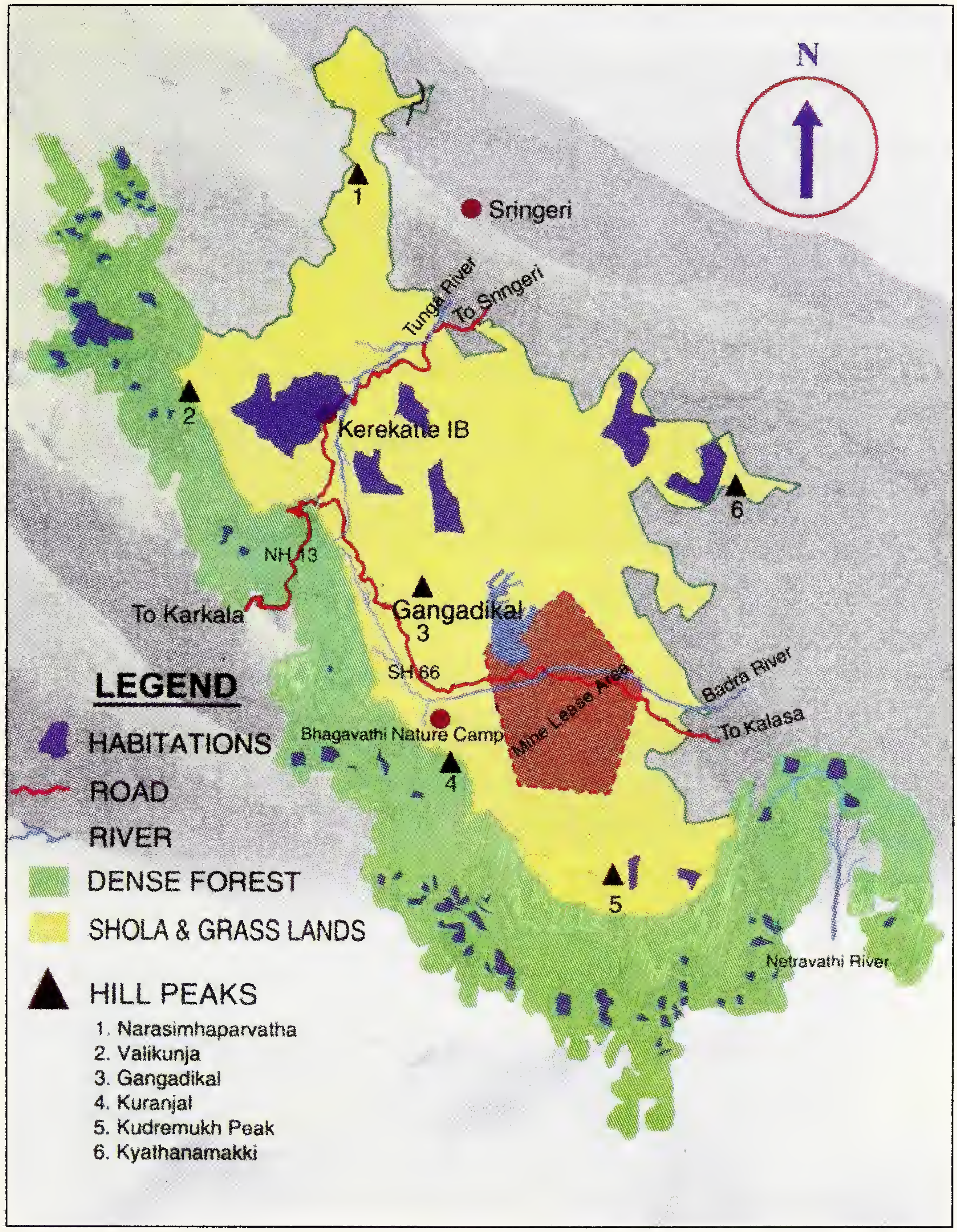
Hussain, S.A.: Kudremukh National Park PLATE 1


N
Sringeri
1
Tunga River
To Sringeri
2
Kerekatte IB
6
NH 13
To Karkala
Gangadikal
3
SH 66
Badra River
Mine Lease Area
To Kalasa
Bhagavathi Nature Camp
4
5
Netravathi River
LEGEND
HABITATIONS
ROAD
RIVER
DENSE FOREST
SHOLA & GRASS LANDS
HILL PEAKS
1. Narasimhaparvatha
2. Valikunja
3. Gangadikal
4. Kuranjal
5. Kudremukh Peak
6. Kyathanamakki

KIND COURTESY: DY CONSERVATOR OF FORESTS, WILDLIFE DIVISION, KARKALA

Fig. 1: Map of Kudremukh National Park

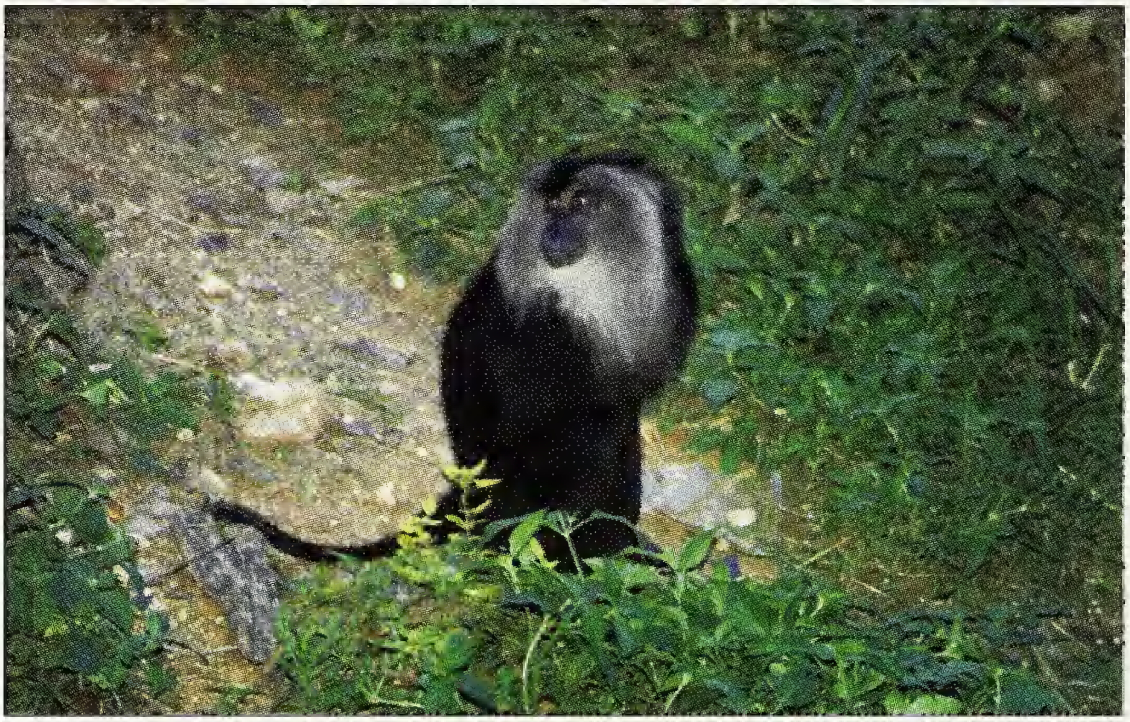
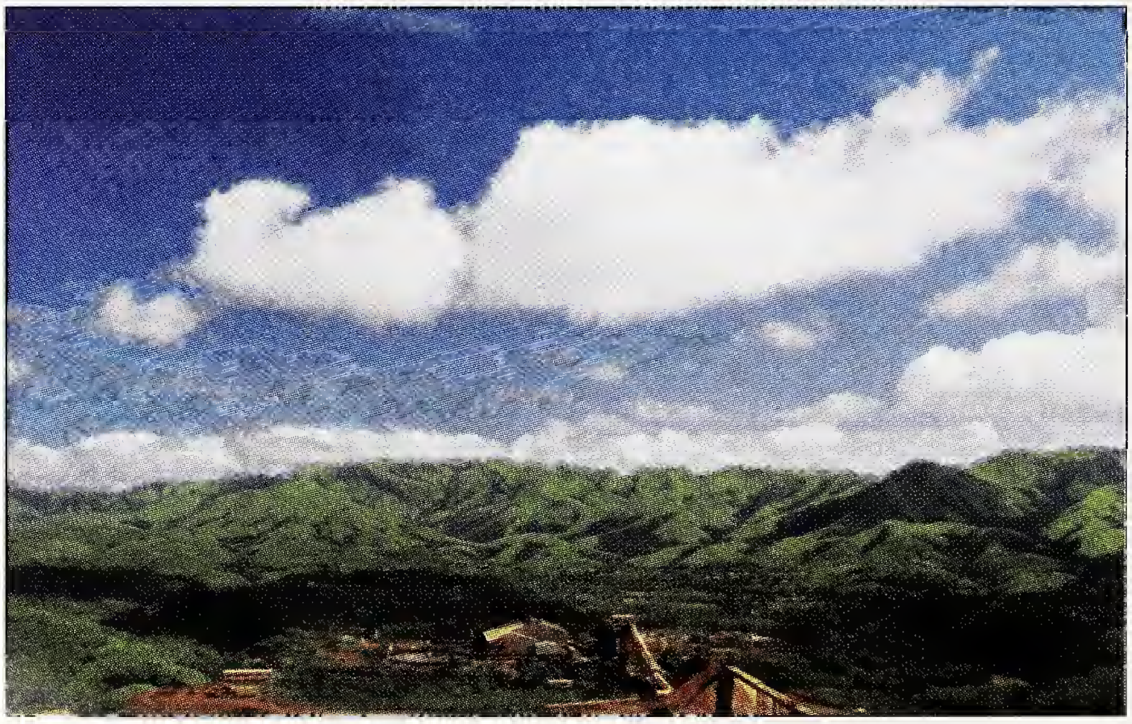


Fig. 2: Liontailed macaque *Macaca silenus*, one of the flagship species of Kudremukh National Park



PICS: S.A. HUSSAIN

Fig. 3: A view of the mining township, from the mining area, within Kudremukh National Park

towards the Bay of Bengal. Two major rivers, the Tunga and the Bhadra originate from the dense Bhagavati Forest. While Tunga flows due north-northeast towards Sringeri, Bhadra flows due east passing through the leasehold of the public sector enterprise, Kudremukh Iron Ore Company Ltd (KIOCL) mining area, both join up near Bhadravati town to form Tungabhadra river, and eventually merge with River Krishna.

The KNP is very rich in biodiversity. The vegetation is typical of the tropical evergreen forests. Though there are inventories and listings of prominent hardwoods, shrubs and herbs, no comprehensive data is available on the total plant species of the entire area.

Over 35 species of amphibians occur here and their density and diversity have been recorded. Over 400 species of birds have been recorded for the KNP area. The KNP hosts 38 species of mammals belonging to 28 genera. Four species are endemic to the Western Ghats; three of them being the liontailed macaque *Macaca silenus* (rare and endangered; Plate 2, Fig. 2), the Malabar civet *Viverra civettina* and the brown palm civet *Paradoxurus jerdoni* (Hussain *et al.* 1999). The fourth is a small isolated population of langur species that has recently been noticed sharing the shola habitat with the liontailed macaque. This langur differs a great deal from the common langur *Semnopithecus entellus* but is closer to the Nilgiri langur *Trachypithecus johni*. It is possible that this may be a distinct species of langur, and more study is needed to ascertain it. These four are the flagship species of [illegible] region.

VEGETATION STRUCTURE

Kadambi (1942a, b) has distinguished 3 types of vegetation structure in the *Poeciloneuron* forests of South Bhadra and Tunga, namely Mixed Evergreen, Semi-pure Evergreen and Pure Evergreen Forests, corresponding to increasing concentrations of *Poeciloneuron*. Rai (1981) has studied the structure and primary productivity in South Bhadra RF (Reserve Forest) corresponding to the gregarious *Poeciloneuron* stands.

The extensive lowland forests comprising Naravi RF and Andar RF and the adjacent Someshwara Wildlife Sanctuary are included under the KNP. These forests comprise mainly of Tropical Evergreen and Moist Deciduous types. Some areas have been extensively planted with teak *Tectona grandis*.

FAUNA OF KUDREMUKH NATIONAL PARK

Ornithology

From the distributional ranges given in available literature, it appears that the total number of bird species occurring in the region could be 400 ±20. These were based on actual sightings in the highland/lowland forests as well as the secondary forests and urban areas of the coastal belt. The tropical forests of the southern Western Ghats (including the coastal areas) harbour a lower diversity of bird species in comparison to similar habitats in African and Neotropical forests. Daniels (1984) estimated that in the evergreen forests of southwestern India, a maximum of 150 species of birds are present in an area less than 15 sq. km, whereas 478 species have been recorded in Ecuador (S. America) and 365 species in Gabon (Africa). The recent rapid changes in the landscape may have caused the disappearance of some species, while some others may have recently replaced these in the changed habitats.

The flagship species of tropical forest birds which are either endemic to the southern Western Ghats or have a patchy distribution of small populations, are represented in the KNP region by great pied hornbill *Buceros bicornis*, Nilgiri wood-pigeon *Columba elphinstonii*, Wynaad laughingthrush *Garrulax delesserti*, grey-breasted laughingthrush *G. jerdoni*, blue-winged parakeet *Psittacula columboides*, grey-headed bulbul *Pycnonotus priocephalus*, white-bellied treepie *Dendrocitta leucogastra*, white-bellied blue-flycatcher *Cyornis pallipes* and Nilgiri flycatcher *Eumyias albicaudata*. Some other species such as black eagle *Ictinaetus malayensis* and Ceylon frogmouth *Batrachostomus moniliger* also occur.

Though the KIOCL mining sector was devoid of any species, surprisingly small patches of remnant shola forests within the actual mining area harboured small populations of habitat specialists. Kudremukh township with a mosaic of urban ornamental plantations intermingling with patches of dense secondary scrub hosted yet another diverse bird population. Lowland forests of KNP also hosted a good species assemblage typical of the area. Two censuses were carried out, at each site in the KNP by the author, results of which are given in Table 1.

Mammals

In the KNP area, endemics are represented by primates (2 spp.) and small carnivores (2 spp.) (Table 2). Except the Nilgiri tahr *Hemitragus hylocrius*, all other endemics of the Western Ghats are found here. The KNP hosts perhaps the single largest population of the flagship species, the liontailed macaque, north of Silent Valley in Kerala. It is estimated that over 200-300 of them occur in the KNP belt with a few other small populations scattered in the lowland forests of Someshwara and Mookambika Wildlife Sanctuaries located north of KNP.

As mentioned earlier, the distinct langur population of the shola forests needs further field

Table 2: Number of genera and species and endemic mammals in KNP

Mammal groups	Genera	Species	Endemics
Primates	3	5	2
Large carnivores	1	2	-
Small carnivores (Felids)	1	4	-
Small carnivores (others)	4	7	2
Canids	3	3	-
Mustelids	2	3	-
Rodents	5	5	-
Deer	4	4	-
Other species	5	5	-
Total	28	38	4

Table 1: A quick analysis of the results of the censuses at Kudremukh National Park (including mining area)

Sampling site	Altitude range above msl (in m)	Distance from core mining area	Habitat/Vegetation	No. of species recorded	Habitat specialist species
Mining site	800-1,000	—	Highly disturbed open grassy hills and small shola patches.	12	3
Kudremukh township	700-800	500 m	Urban area with plantation and gardens.	32	0
Samse village	800-1,000	5 km	Mosaic of plantation, shola and scrub.	26	2
Gangrikal	800-1,500	8 km	Shola and grasslands.	22	5
Lakya Dam, backwaters	900-1,000	3 km	Water reservoir surrounded by grasslands and monoculture plantations.	6	0
Naravi Forest	300-600	15 km	Dense lowland forests.	36	4
Horanadu	800-900	15 km	Deciduous scrub. Rain-shadow area.	6	0

and DNA research to ascertain its specific status. The other species reported recently is the rare and endangered Malabar civet (*Viverra civettina*), small populations of which have been frequently reported from Mookambika and Someshwara Wildlife Sanctuaries as well as lowland and highland forests of KNP.

The Indian gaur *Bos gaurus* is the largest common ungulate occurring in both lowland and highland forests of KNP, followed by sambar *Cervus unicolor* and chital *Axis axis*. These are the most common animals in the area. However, large-scale forest clearing for agriculture and human settlements in the past 100 years, particularly in the lowland forests, has fragmented their populations into smaller herds, frequently bringing them into conflict with human settlements. The populations of their natural predator, the tiger *Panthera tigris* has also reduced due to anthropogenic pressures. However, in 2001, a tigress took residence very close to the mining area and raised two cubs. As everywhere else in the region, the leopard *Panthera pardus* is still holding its own, particularly in the secondary mixed forests and mosaic vegetation.

It is estimated that over 150 liontailed macaques are present in the KNP, most of which are confined to heavy rainfall areas of shola/ grasslands of Bhagavati Forest, Tungabhadra State Forest (Kerekatte) and steep western slopes of the ghats and lowland forests of Andar and Naravi Reserve Forests (more than 200 m above msl). A total of ten troops were encountered by the author. These are listed in Table 3.

The occurrence of the unidentified langurs needs further observation. This population which may have been overlooked so far by earlier workers needs to be studied to determine whether they are a distinct and new species. The animals are small, with very dark and thick coat and pale brown head, slow moving in the canopy and confined to dense highland forests of KNP.

Table 3: Troops of liontailed macaques encountered at KNP

Site	Habitat	No. of troops	No. of individuals per troop
Gangrikal shola complex	Shola/ grassland	4	14, 8,10 & 9
Kadambi / Bhagavati	Evergreen	2	8 & 7
Kerekatte	Evergreen	3	12, 11 & 9
Agumbe	Evergreen	1	10
Total		10	98

Elephants *Elephas maximus* are very rare in KNP, though there have been occasional individuals straying in the periphery of the Park. In 2001, three individuals came up the pipeline road and stayed within the Park. This population is more or less resident now. Several species of bats occur in both lowland and highland forests.

RESOURCE EVALUATION

The Western Ghats of Karnataka possess some of the most pristine lowland and highland forests in the entire Western Ghats chain. Though these forests have gradually been fragmented into smaller disjointed stretches of Evergreen, Moist Evergreen, Moist Deciduous, mixed scrub, and regenerating woodlands, the diversity of mammalian fauna still holds out on its own in smaller pockets. The transitional belt of lowland forests of the coastal zone and highland forests of steep hill slopes, culminating in the specialised vegetation of hill crests which then gradually stretch eastwards into a rolling mosaic of forests mingled with plantations, host a number of species including some rare endemics. The rich wildlife of the area is underscored by the fact that two national parks and several wildlife sanctuaries straddle the Western Ghats.

The Kudremukh National Park serves both eastern and western regions of the Western Ghats. The major portion of Malnad area and the entire district of Udupi and Dakshina Kannada depend on the water regime emanating from the Kudremukh area. The districts in the immediate vicinity served are Shimoga, Chikmagalur and Hassan in the east and Udupi and Dakshina Kannada in the west. Several perennial and seasonal streams/ rivulets/ rivers exist in the KNP area. Among the east flowing rivers, Tunga and Bhadra and their tributaries Varada and Hagari have their origin within KNP with a catchment area of 684.4 sq. km and total length of 528 km. The two rivers join up after Bhadravati town to become the Tungabhadra river.

The west flowing, perennial Sita, Suvarna, Udyavar, Mulki, Gurpur and Nethravathi rivers serve the Udupi and Dakshina Kannada districts and their total catchment area is over 8,326 sq. km and total spread area is 833,595 ha. The average annual rainfall here is 4,420 mm. The extent to which the villages around KNP depend on these freshwater sources — in terms of irrigation, fishing, daily consumption, number of people served — is given in Table 4. The following are the crops that depend on the freshwater sources:

A. North, east and southwards: Tea, coffee, cardamom, pepper, arecanut and paddy in the immediate surroundings. Paddy, sugarcane, banana, cereal crops, etc. in the down river basin and command areas of Tunga and Bhadra dams and other regions right up to the Bay of Bengal.

B. Westwards: Coconut, rubber, arecanut, paddy, sugarcane, and other crops.

Table 4: The figures showing the dependence of Dakshina Kannada and Udupi on the rivers flowing out from KNP

Total agricultural land	286,000 ha
Groundwater -	
Domestic consumption	43.7 million cu. m/year
Irrigation	427 million cu. m/year
Total estimated consumption	471 million cu. m/year
Annual replenishment	1,245 million cu. m/year
River outflow – annual average	29,561 million cu. m/year
Coastal fisheries – annual average catch	143,000 tonnes
Population of the districts (Udupi & D.K.)	2.69 million (in 1961)
Density	319 per sq. km

Compiled from various sources

HUMAN IMPACT EVALUATION

The area has no legally permanent human settlements, except for a few communities that have existed here for a long time. Even in the periphery of the Park, particularly along its eastern and northern boundaries, the human population is sparse and widespread among plantations and small holdings of cultivated fields. Unlike other national parks and sanctuaries, anthropogenic pressures on the vegetation for fuel and other needs are minimal in KNP. However, as is happening in other developing countries of the tropics, there are many problems faced by the KNP ecosystem. There have been recent cases of large-scale encroachment of Park forests in the periphery by rich landholders for illegal extension of coffee and other plantations. The KIOCL township is the only and the most populated human habitation in the KNP (Plate 2, Fig. 3). The total human population of the township was estimated to be 10,636 (1991 Census). Though actual figures are not available, it is estimated that 350-450 privately owned cattle (mostly cows and a few buffaloes) exist in the Park area. A list of the enclosures in the Park is given in Table 5. Encroachment of forest land by marginal farmers, large plantations, as well as cattle graziers is becoming a serious problem.

The major activity in the Park ecosystem is of iron ore mining by the public sector Kudremukh Iron Ore Company Ltd (KIOCL). The company has been operating here since 1980 in the leased area. Most of the actual mining is in grass topped bare hills (370 ha) with scattered small sholas.

Table 5: Details of occupied land within Kudremukh National Park

a:

Range	No. of enclosures	No. of families	Total land holding (in ha)
1. Karkala Wildlife Range, Karkala	34	140	238.28
2. Venoor Wildlife Range, Belthangad	32	256	797.92
3. Sringeri Wildlife Range, Kerekatte	17	1,009	1,273.02
4. Kudremukh Wildlife Range, Kudremukh	08	54	80.26
	91	1,459	2,389.48

b:

1. Total extent of land leased to KIOCL	4,605.02 ha
2. Extent of forest land leased	3,203.55 ha
3. Extent of forest land converted inside leased area	1,452.74 ha
4. Extent of forest land converted for pipeline outside the leased area	30.00 ha
5. Extent of forest land likely to submerge outside the leased area due to raising of dam height	340.00 ha
6. Total forest land being utilised by KIOCL	1,822.74 ha

Areas that have some level of threat to wildlife and its habitat

Of the entire 600 sq. km area of the Kudremukh National Park (KNP), some level of threat to wildlife and its habitat is present at its extreme eastern border where the KIOCL has its operations. The mining concession and its surroundings are a hilly terrain, mostly covered with grasslands and small stunted shola patches. These grasslands were originally the traditional grazing (*gomal*) lands for the cattle of the villages nearby. In fact, right in the Park premises there are a couple of private holdings rearing about 200-300 cattle which freely graze around.

On the whole, the mining concession with its establishment, mines, processing area and township is located very close to the eastern and traditionally exploited border of the Park. Tea, coffee, cardamom, pepper and areca plantations as well as paddy cultivation are the major agricultural activities in this area. Due to mosaic vegetation (some good forest patches and tree cover interspersed with villages and cultivation), there is a good bird and insect diversity, with some wild animals such as wild boar, sambar, barking deer and other smaller mammals moving in and out. These have adapted well to local conditions.

The major impact of mining is on the Bhadra river system which passes through the immediate vicinity of mining fields and is subjected to a heavy silt load, particularly during the first onslaught of monsoon rains in June-August. Incidentally, this is the period when most of the hill stream fish, amphibians and other microfauna of the terrestrial system begin to regenerate and a very critical period for the biodiversity of not only local but also major downstream river systems. The main grouse of the villagers and farmers downstream is that the silt load renders the water unfit for drinking and/or cultivation, particularly in the monsoon period. Cumulative effect over the years may have far reaching consequences in the Bhadra river system.

Heavy grazing by village cattle, ill-advised plantation on true grasslands in the KIOCL lease area as well as other grasslands in the Park with exotic *Acacia auriculiformes*, *Eucalyptus*, *Casuarina*, etc., and frequent setting of fire to grasslands without any scientific study on regeneration profile (which has led to colonisation of grasslands by weed-like fern species, depleting the grass available as food for wildlife, particularly gaur and sambar), are some of the major problems faced here.

Fortunately, the bulk of the dense pristine, Tropical Wet Evergreen and the Shola Forests as well as the grasslands are well away from the KIOCL and preserved by the sheer hilly terrain.

Except for the road from Mangalore to KIOCL, the area is comparatively free of human presence. The core area of the KNP is dense and well preserved due to its inaccessibility. This area, which comprises the central and western portion of the KNP, is home to the liontailed macaque, gaur, sambar, and many other smaller mammals, amphibians, reptiles and birds. Some scattered, old, legal settlements are present in this area but these are not very obvious, and as such there is not much disturbance to wildlife. These settlements need to be taken into account in the management plan of KNP as a long-term policy. A newly created national highway passes through the dense forests of the western region of KNP. Some strict measures have to be taken to see that no widening of the road and/or illegal encroachments take place here.

The creation of a separate Kudremukh Wildlife Division with its headquarters nearby is a major step taken by the State Government. However, like many of the government departments, this division is under-equipped and under-staffed with meagre budget allotments. The Division controls the gates, carries on fire protection measures, has established and maintains medicinal plant preservation plots in the Park besides a nature camp with visitor facilities, and carries out anti-poaching patrolling. The current DCF-Wildlife is a dedicated conservationist with a no-nonsense approach to forest protection. However, a scientifically designed management plan for the KNP has not yet been prepared and there is an immediate need for this. Local conservationists and experts should be involved by the Kudremukh Wildlife Division to prepare a comprehensive management plan for the KNP.

KIOCL must be made to pay full compensation and royalty to the Wildlife Department for the exploitation they have carried out so far and are continuing. This royalty could be given out of the profits the KIOCL earns from exploiting the resources. This could be anywhere between 8-10 crores per annum and the amount can be utilised for research, conservation and maintenance expenses of the KNP. This is only the compensation for past and existing exploitation, and should be considered as a penalty. New areas should *never* be given to KIOCL for mining.

POSSIBLE FUTURE COURSE OF ACTION

Rationale

Sooner or later, the KIOCL may have to close down the mining operations at Kudremukh and pull out their establishment from the area. This will happen either due to pressure from environmental concerns and the Supreme Court directives or by the sheer economics of mining in the area. For one, the deposits will be exhausted very soon and there is very little chance of permission being given for additional mining concessions in either nearby Nellibeedu or at Gangrikal which is in the 'sanctum sanctorum' of the KNP.

The township (area 320 ha, population *c.* 10,000 in 1991) currently maintained by KIOCL has all the modern facilities including water supply and sewage treatment/disposal (see Appendices I and II). The layout of the town is well designed in an undulating landscape. Most of the original shola/grassland mosaic remains untouched between various housing sectors, giving it a natural look. An indicator of the naturalness is the presence of a large number of birds of Tropical Evergreen Forests, reptiles (including king cobra), and occasional barking deer, sambar, gaur, and giant squirrels that frequent the periphery of the township.

The town also has all the modern amenities such as STD/ISD, Cable TV network, a well maintained public park, half-hourly bus services (greater part travelled through the National Highway to Mangalore, *c.* 85 km, 2 hour drive) to the nearest airport/railway station.

Inevitably, KIOCL will have to surrender the mining lease and the land will have to be reverted and added to the National Park. All the infrastructure that lies within the township and the mining area needs to be dealt with somehow.

For the KIOCL there are two choices:

a. Demolish all structures and establishments in the township and mined area (and leave behind a ghastly concrete/steel rubble of a ghost town), or
b. Hand over the main structures to an appropriate agency (National Park Authority) for possible future action/usage along with substantial seed money to deal with it.

Considering the fact that the area will legally be reverted back to a National Park and as such a full-scale independent township cannot exist within the Park, private commercial activities cannot be allowed, nor can there be any chance of promoting a holiday resort or a hill station for tourist activities. Perhaps the only pragmatic way to overcome this dilemma is to utilise the existing infrastructure to establish some kind of regional/national research/convention centre. The following possibilities can be seriously considered after setting up an appropriate taskforce with a mandate to devise ways and means to achieve the desired and pragmatic objectives.

Recommended course of action

Constitute a taskforce with a definite mandate and time frame to:

a. Conduct a preliminary feasibility study and report,
b. Negotiate with KIOCL and all the likely stakeholders,
c. Prepare an appropriate Action Plan,
d. Source out funding regimes (including income generating schemes - e.g. facilities can be hired out as an international/national environment, scientific and conservation related conference and convention centre).

The possible nodal agencies to be involved are given in Appendix III.

Some immediate recommendations

1. Stop all "afforestation schemes" and avoid plantations on either grasslands or deforested areas. The tropical rainforest is *capable of regenerating itself*, provided it is given adequate protection.
2. Monitor the growth of pioneer species in open areas and control the spread of any alien weeds.
3. Carry on experiments in the broken up mining areas to find the best way to encourage re-colonisation of pioneering species such as *Buddlija asiatica*, *Blumea oxydonta* and *Crotalaria pallida*.

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Appendix I: Existing facilities at KIOCL township

Permanent structures (other than mining area):

Structure	Facilites	Number
Administration building	3 stories with *c.* 100,000 sq. ft space	1
Sahyadri Bhavan (Guest House)	50+ rooms (A/C, non A/C), clubhouse, seminar halls, fully equipped modern kitchen & dining hall, swimming pool, etc.	1
Hostel	48 rooms + dining	1
Public hall + stage	500 seating capacity	1
Hospital + 0T & amenities	40 bed capacity	1
Staff quarters (flats)	A - single	172
	- family	1,018
	B - single	88
	- family	405
	C - single	52
	- family	156
	D - senior (bungalows)	48
Total (flats)		1,939
Mini shopping complexes	In different sectors of the township	7
KIOCL Training Centre	Details not available	—
CISF barracks + offices	Details not available	—
Public utility buildings	Post Office, Banks (3), Police station, Bus stand (mofussil & long distance)	6
Educational institutions	Central school, Convent school, Primary & High school, P.U. College , Computer center + internet facilities	6
Helipad	Heliport + VIP lounge	—
Wildlife Dept offices	ACF/RFO offices & Staff quarters	5
Places of worship	Temple, Mosque & Church	3
Lakya dam & backwaters	Freshwater source & sanctuary for hill stream fish, otters and other species	604 ha

Data compiled from different sources.

Appendix II: Current annual maintenance expenses (staff salaries not included)

Works	Amount Rs. (in lakhs)
Civil works/road maintenance etc.	189
Electricity/street lighting etc.	23.3
Recreational park	36
Annual total	248.3

Appendix III: Possible agencies to be involved in deciding the future of KIOCL

Nodal agencies: Ministry of Environment & Forests, Government of India (MoEF/GOI)
Karnataka State Ministry of Environment & Forests.

Stakeholders: MoEF/GOI:
- Zoological Survey of India
- Botanical Survey of India
- Forest Research Institute, Dehra Dun
- Wildlife Institute of India, Dehra Dun
- Department of Science & Technology (DST)
- Indian Council for Agricultural Research (ICAR)
- University Grants Commission (UGC)
- Any other appropriate agency

Karnataka:
- State Wildlife Department
- State Forestry College
- University of Agricultural Sciences (UAS), Bangalore
- Centre for Ecological Studies, Indian Institute of Science (CES/IISc)
- Indian Remote Sensing Agency (IRSA)
- Indian Space Research Organisation (ISRO), Bangalore
- Kuvempu University, Shankarghatta, Shimoga
- Any other appropriate agency

NGO/Institutions:
- Bombay Natural History Society (BNHS), Mumbai
- Sálim Ali Center for Ornithology & Natural History (SACON), Coimbatore.
- Any other national agency

Funding sources:

National:
- Government of India - MoEF
  - Ministry of Science, Technology & Space
  - Ministry of Agriculture
- Government of Karnataka - MoEF

International:
- United Nations Development Program (UNDP)
- United Nations Environment Program (UNEP)

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DEVELOPING RESPONSIVE INDICATORS FOR THE INDIAN BIOSPHERE RESERVE PROGRAMME

Anirban Ganguly[1], Yogesh Gokhale[2,3] and Madhav Gadgil[2,4]

Key words: Biosphere Reserves, India, indicators, monitoring and evaluation, community participation

Biosphere Reserves (BRs) are intended to reconcile challenges relating to conservation and sustainable use of biodiversity, social and economic development and maintenance of associated cultural values. In keeping with these objectives, India has established a network of 11 Biosphere Reserves. The study attempts to evaluate the performance of these BRs using a set of indicators relating to community participation, legal and institutional mechanisms, management capacity and effectiveness. The specific indicators relate to the Indian context and give special attention to issues like people-wildlife conflict, understanding of programme objectives at various hierarchical levels, continuance of traditional conservation practices and promotion of scientific research. Indian BRs have, by and large, failed to resolve or even added to resource conflicts due to inter agency disputes or imposition of an inappropriate model of development. Moreover, major management decisions seem to be taken at higher bureaucratic levels without reference to livelihood concerns of local people and traditional resource management systems followed in local areas. On the other hand, Indian BRs have been successful in areas like supplementary income generation. The study also points to a methodology of using 'discriminatory' performance indicators which would be adequately sensitive to the proximate needs of ecologically handicapped communities.

INTRODUCTION

Biosphere Reserves are intended to reconcile challenges relating to conservation and sustainable use of biodiversity, social and economic development and maintenance of associated cultural values (UNESCO 1996). In keeping with these objectives, India has established a network of eleven Biosphere Reserves till October 1999. Out of these eleven, only three — Nilgiri, Gulf of Mannar and Sundarban — are recognised under UNESCO's Man and Biosphere programme as of May 17, 2002 (http://www.unesco.org/mab/brlist.htm). The present study attempts to evaluate the performance of these Reserves, using a set of indicators relating to community involvement and participation, legal and regulatory mechanisms, management capacity and effectiveness, drawing from a number of case studies.

The idea of Biosphere Reserves was mooted by UNESCO in 1973-74 under its Man and Biosphere (MAB) programme. Biosphere Reserve (BR) is an international designation coined by UNESCO for representative parts of natural and cultural landscapes extending over terrestrial or coastal/marine ecosystems. In India, BR is not a legal conservation category, unlike Wildlife Sanctuaries and National Parks. However, areas earmarked as BRs often overlap with areas which are legally protected, often resulting in conflicting plans and programmes.

MATERIAL AND METHODS

Field experience

One of the authors (MG) has been associated with the Indian Biosphere Reserve Programme since its early beginnings in 1980. At that time, he was commissioned by the Government of India to prepare the project document for the

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establishment of the Nilgiri BR. This subsequently became the first biosphere reserve to be established in 1986. The Centre for Ecological Sciences established a Field Research Station in the Nilgiri BR in that year and has been continually involved in monitoring the functioning of that BR since its inception. In 1992, the Ministry of Environment and Forests (MoEF), Government of India commissioned the Centre for Ecological Sciences (CES), Indian Institute of Science, Bangalore in 1992 to undertake a mid-term review of the Biosphere Reserve Programme. As a part of this exercise, Madhav Gadgil and R. Prabhakar undertook a specific review of the Nilgiri BR and Niraj Joshi undertook field visits to the following Biosphere reserves: Gulf of Mannar, Nandadevi, Nilgiri, Nokrek, Manas and Sundarban. This mid-term review was followed in 1993 by a training programme for the managers of the biosphere reserves in India at Mudumalai Wildlife Sanctuary in Nilgiri BR, which provided an opportunity for obtaining further inputs on the BR programme. Hans Raj Negi of CES conducted extensive field research in the Nandadevi BR during the years 1994 to 1997.

Subsequently, the Biosphere Reserve Programme was once again reviewed by CES in collaboration with RANWA, an environmental group, in 1996-98 as a part of the Biodiversity Conservation Prioritisation Programme (BCPP) of WWF-India. Under this programme, collaborative field visits were undertaken in the following Biosphere Reserves:

Biosphere Reserve	Collaborator
1) Gulf of Mannar	Winfred Thomas, American College, Madurai, Tamil Nadu
2) Nandadevi	Omprakash Bhatt, Dasholi Gramswarajya Mandal, Chamoli, Uttaranchal
3) Nokrek	Nature's Beckon, Dhubri, Assam
4) Manas	Nature's Beckon, Dhubri, Assam
5) Sundarban	Silanjan Bhattacharyya, Kolkata, West Bengal

The data collection has involved interviews with forest and other government officials, local people, researchers, and NGOs working in the area. Several field visits were conducted for rapid assessment of the various components of the BR programmes at various Biosphere Reserves by one of the authors or by the collaborators mentioned earlier. Secondary information sources in the form of reports, newspaper articles and official documents were also referred to.

Evaluation methodology

Of late, there has been a proliferation of literature on the evaluation of developmental interventions. The World Bank, World Resources Institute, IUCN and Biodiversity Support Program of WWF, for example, provide detailed guidelines on the kind of scientific and economic indicators which may be used to evaluate the performance of a wide range of projects. These range from country-specific biodiversity indicators like percentage of major forest types covered in a protected area network, as suggested by IUCN, to broader region-oriented measures like change in institutional or management structures leading to change in resource utilisation practices. These indicators have been extensively applied to assess the efficacy of funds provided at the international level, both by specialised funding mechanisms like the Global Environment Facility (GEF) and by bilateral donor organisations and aid agencies like DANIDA and NORAD. Of late, there is also a tendency to use indicators sensitive to equity concerns, specifically from the angles of gender and socially/economically disadvantaged communities.

At the same time, there has also been a major development in the economic and socio-political theory in the area of cost-benefit analysis and broader evaluation techniques. The major landmark in this regard would be the development of the Guidelines for Project Evaluation by UNIDO, Vienna (Dasgupta *et al.* 1972). These guidelines spell out the economic rationale behind project choice, evaluation and monitoring using models of uncertainty and social choice. From then onwards, there has been a rapid growth of understanding on the valuation of ecosystem functions (Barbier 1992, Dixon 1992) and the social consequences of disruptions of such functions (Ruitenbeek 1992, Munasinghe 1990). Also, one school of economists, pioneered by Amartya Sen, have emphasised the use of discriminatory analytical tools like weighted indices of human development to assess programme level interventions, since indices which are aggregative or even relative at an inappropriate scale tend to suppress major equity and (re)distribution concerns. In his recent work DEVELOPMENT AS FREEDOM, Sen (2000) advocates the use of analytical tools that view development as a process of expanding substantive freedoms, reflected in socio-economic arrangements (e.g. health and educational facilities) and political/civil rights (e.g. the freedom to participate in public discussion and scrutiny). Performance evaluation of development interventions, when informed by such a view, involves active consideration of the ability of an intervention to achieve tangible enhancements in freedoms of the target groups, such as increased capacities of individuals and groups to indulge in public debate on issues that affect their livelihoods and lifestyles.

There is clearly a need to harmonise these two streams of literature in order to develop a set of responsive indicators for evaluation of interventions at project and programme levels. We make here a distinction between project and programme levels because project interventions very often follow from strategies developed at the programme level. Thus, reasons for success or failure of a specific project could lie both in problems intrinsic to the project itself or be the result of incorrect strategisation or poor learning at a higher decision-making level which gets reflected in project implementation phases. In this paper, our focus is on the use of indicators to make a programme level evaluation of the Biosphere Reserve programme, as implemented in India.

These indicators should, on the one hand, test the efficiency of financial, technical and management inputs provided in terms of a set of carefully designed criteria, and on the other hand be adaptive enough to ground realities so as not to miss out relevant equity and social justice concerns. These concerns are almost always region and culture specific and, therefore, difficult to aggregate over projects. For example, increase in human-tiger conflicts in the Sundarban BR area — and the resultant agony of local communities — is now a part of local cultural ethos or even the mindscape of local communities. It is impossible to weigh this against reduced conflicts in other areas or offset positive economic indicators against the psychological cost of loss of a family member or living a differently-abled life.

The currently adopted evaluation methodology could draw from the rich literature now available in a range of disciplines including social choice, information and uncertainty theory, while the theoretical literature can be enriched through the use of appropriate case studies and best practice lessons. International funding mechanisms such as GEF do undertake programme implementation reviews periodically; such reviews can also inform and enrich the theoretical literature in many of these fields. For instance, case examples of how communities do or do not exhibit group rationality when involved in a donor driven programme can be a key input to social choice literature. In arid areas of Rajasthan, water harvesting initiatives supported by external funders have been most successful when local communities have been mobilised by local NGOs to bear a significant component of the programme cost; in other words, the ability of a community to translate its group decision-making behaviour to actual burden sharing (financial or otherwise) is a requisite to the sustained success of a resource 'wise-use' programme (Rajender Singh, Tarun Bharat Sangh, pers. comm.).

An attempt at harmonisation of these two streams of literature on evaluation methodology and Biosphere Reserves is made in the following paragraphs, drawing from available case studies and personal experience of the authors with regard to the Indian Biosphere Reserve Programme.

THE CASE OF INDIAN BIOSPHERE RESERVES

Biosphere Reserves, as mentioned earlier, are areas of terrestrial and coastal/marine ecosystems or a combination thereof, earmarked for innovative conservation and management (an alternative to the National Park/Wildlife Sanctuary model) and motivated by the framework of UNESCO's Man and Biosphere Programme. Each Biosphere Reserve is intended to fulfil three complementary functions: a conservation function — to preserve genetic resources, species, ecosystems and landscapes; a development function; and a logistic support function — to support demonstration projects, environmental education and so on. Biosphere Reserves are not covered by an international convention, but must meet a set of criteria allowing them to fulfil properly their three functions. A number of Biosphere Reserves simultaneously encompass areas protected under other systems (such as national parks or nature reserves) and other internationally recognised sites such as Ramsar wetland sites.

India launched its own Biosphere Reserve Programme in 1979. Currently, 11 Biosphere Reserves — Nilgiri, Nandadevi, Nokrek, Gulf of Mannar, Manas , Great Nicobar, Sundarban, Dibru-Saikhowa, Simlipal, Dehang Debang and Pachmarhi operate in India. In addition, Namdapha, Valley of Flowers, Thar Desert, Rann of Kutch, Kanha and the North Islands of Andaman have been identified by the Indian Man and Biosphere (MAB) committee as potential sites for BRs.

The extent to which this network of BRs has fulfilled its multiple objectives could be evaluated using a carefully selected set of indicators. We provide below a sample of such indicators, using available information and insights gained from personal fieldwork. These are by no means exhaustive; rather they are indicative of how a development intervention may be evaluated in a responsive and adaptive way.

Extent of awareness about goals of the programme at various hierarchical levels

Changes in levels of information about programme objectives and implementation at various hierarchical levels would be an important indicator of management capacity and effectiveness. In the context of Biosphere Reserves, such an understanding is, to a great extent, available at international and national levels, but not at the State or local levels. Indeed, the ability of local people to appreciate the objectives of a development intervention is a requisite for their involvement at various levels of planning and implementation. Our experience suggests that people living inside a Biosphere Reserve area rarely have any idea of the objectives of the programme, though people are more conscious of other conservation categories, like National Park, overlapping with a BR area.

Moreover, there is often a different kind of understanding available at the local level that does not get transferred upwards. For example, in the Nandadevi BR, banning of seasonal grazing in the alpine meadows, locally called *bugyals*, inside the BR (core area) has affected traditional livelihoods; at the same time, locals believe that this has reduced the diversity of medicinal herbs, replacing them with extensive growth of a few species — a development not accounted for in plans decided higher up (Hans Raj Negi, pers. comm.) .

Incorporation of local management and cultural practices

The degree to which a development intervention incorporates existing management and cultural practices could be an indicator of its responsiveness. The costs imposed on specific communities as a result of a course of action taken at a large physical (and hierarchical) distance are typically undervalued. In this regard, the Indian Biosphere Reserve Programme seems to have performed poorly as there have been few systematic studies in this area (an ongoing study on Bhotias, a nomadic tribe in Nandadevi BR undertaken by the Wildlife Institute of India is a notable exception). Consequently, development plans have gone haywire; tribes like Shompens, for example, have refused to accept a development model based on improved access to amenities unrelated to their cultural perceptions. Ecotourism plans have similarly missed out the need to merge local cultural practices (represented through performing arts, for example) as a part of the development strategy.

In many cases, locally evolved conservation practices still continue in a limited way. The Bodo tribals in the Manas BR area protect parts of the forest as sacred groves — a practice which harmonises well with the concepts of supply and safety forests. The Bodos also maintain their traditional varieties of crop species (whereas Assamese, Bengali and Nepali settlers in the area have taken to cultivating high yielding varieties), while the Bodo practices still continue. Bhotias of the Nandadevi BR area graze their livestock and collect medicinal herbs from alpine meadows, maintaining an optimum grazing level to ensure a continued supply of herbs.The closure of the core zone of Nandadevi BR to human activities has deprived local communities of their traditional health practices.

There is also significant local knowledge available with fisherfolk all over India. The fisherfolk on Moyar in the Nilgiri BR are able to describe in great detail the time course of siltation and shallowing of the river stream and the consequent changes in fish fauna. However, very little official documentation is available on the aquatic ecosystems of most Indian BRs. Again, herders in Nandadevi BR narrate the changes in the alpine meadows following the grazing ban, pointing to the disappearance of several medicinal plant species. Such knowledge almost never plays a meaningful role in management plans for Indian BRs.

Enhancement of entitlements

Improved access to a basket of goods and services consistent with livelihood needs indicates the success of the development function of Biosphere Reserves. However, this kind of indicator is to be used with caution when the alternative livelihood activity imposes non-monetised costs on specific communities. Thus, loss of family members due to dependence on a hazardous activity needs to be suitably weighted against additional income generation. In other words, additional incomes, as Sen (2000) argues, need to create an expansion of 'human freedoms' and elimination of 'human unfreedoms'.The 'unfreedoms' are typically imposed by historical disadvantages or ecological vulnerability. The Indian Biosphere Reserves seem to have performed well on the income generation criteria alone but not so much when judged by the costs-imposed criterion.

In income generation activities, the role played by voluntary agencies deserves mention. In the Sundarban BR (SBR) area, a number of NGOs currently operate, most notably the Ramkrishna Mission Lok Shiksha Parishad (RMLSP) and the Tagore Society for Rural Development (TSRD). Both these organisations play a potent role in making people appreciate the development objectives of Sundarban BR. TSRD, for example, has set up handloom weaving and honey processing units in the Sundarban BR area, with a view to providing alternative employment opportunities (alternative to uncontrolled brackish water aquaculture and forest based livelihoods). These units serve an important development function, relieving pressures on forest based occupations and reducing human hazards due to human-wildlife tensions. Similarly, RMLSP works in direct collaboration with the

Sundarban BR directorate to involve local people in the social forestry programme and other eco-development activities. This is a step in favour of merging the conservation and development functions of BRs, though an overwhelming majority of farmers are totally ignorant of such efforts. This leads us to the issue of strengthening extension functions of a BR programme; at the programme level, inadequate attention given to resource based extension activities reduces the impact of the interventions being implemented by the non-governmental sector.

While the Sundarban BR has successfully created income opportunities through agriculture, aquaculture and cottage industries, it has failed to reduce man-tiger conflicts due to continued dependence of the Tiger Reserve fringe population on non timber forest produces (NTFPs). In the Sundarbans, about a million people living close to the Project Tiger area have been heavily deprived of access to their traditional resource bases inside the forest areas, due to restrictions imposed by the project. This suggests that income generation schemes have not harmonised well with traditional livelihoods or have been planned on an inadequate scale.

Moreover, human development as measured by access to a bundle of amenities like healthcare, primary education and telecommunication is not seen as an integral part of the development component of the Biosphere Reserve strategy, especially in remote areas of Nokrek and Nandadevi BR.

People-nature conflicts

The degree to which conflicts between a community and its resource catchment zone, defined by livelihood imperatives, are reduced due to a development intervention would be an indicator of its sustainability and effectiveness. On this count, Indian Biosphere Reserves have clearly failed with such conflicts reported from six of them.

Absence of employment options during slack periods has, for example, led to frequent people-tiger conflicts in the Sundarban BR. Sundarbans, the only mangrove habitat with a tiger population, has an interesting ecological history. The British government had settled large numbers of landless people from Midnapore district and the neighbouring state of Orissa, in the area, to maximise revenue earnings from the land. When Project Tiger was launched in 1973 and access to the forest was curtailed, little attention was paid to the biomass needs of the local population and major livelihood activities like NTFP collection were compromised. Prawn fishing gradually became the major livelihood activity but in the absence of genuine alternatives in the slack season, people still entered the forest. Man-tiger conflicts became frequent enough to turn tigers into man-eaters. Man-crocodile conflicts also increased due to over-dependence of local people on fishing. The typical approach to resolving these problems has been to try to change the behaviour of tigers, so that they do not attack humans. Efforts to check the aggression of tigers have included schemes in which tigers are habituated to drink fresh water (based on the view that drinking of salt water is the cause of the unusual aggression of Sundarban tigers). The root solution to the problem lies in tailoring the development functions of the BR programme to create long-term livelihood options for the people affected by these conflicts.

Manas BR also overlaps with a Tiger Reserve area which does not have a buffer zone on its southern periphery. Consequently, man-tiger conflicts are very common, as human habitations abut on restricted areas. Man-crocodile conflicts pose a major problem in Great Nicobar BR as all rivers in the region have significant crocodile populations. Indeed, most Indian BRs have failed to reduce such conflicts because of inadequate integration of its development goals with the conservation goals of the legally conserved areas with which they overlap.

MANAGEMENT PLANS

Legal framework

The extent to which the legal framework in a country harmonises with an intervention is an indicator of its effectiveness. The Indian legal system, for example, recognises National Parks and Wildlife Sanctuaries, but not Biosphere Reserves, as legal entities and thus imposes purely conservation-oriented restrictions on protected areas. Biosphere Reserves frequently overlap with such protected areas and consequently are governed by the relevant laws, which may not be compatible with the BR programme objectives. This leads, for example, to total prohibition of economic activities like grazing in Nandadevi BR, as mentioned earlier, depriving a community of its livelihood and development needs.

Simultaneously, zonation based on short-term calculations has led to severe imbalances in several areas. In the Manas BR, for example, paddy fields and tea estates extend right up to the southern boundary core zone of the designated Tiger Reserve. Till about two decades ago, this area was mostly covered by grasslands and deciduous forests and was inhabited by a few Bodo tribals. Today, refugees from neighbouring Bangladesh have settled in these areas. An area which could have been a natural buffer between the densely populated Brahmaputra Valley and the Tiger Reserve area is now deforested and cultivated.

Inter-agency collaboration

The extent to which various government departments and agencies coordinate among themselves in the implementation of a programme also indicates its effectiveness. The Indian Biosphere Reserve programme seems to have performed inadequately in this regard. Thus, there is a lack of coordination between the Sundarban Development Board (SDB) and the Forest Department on the issue of mangrove plantation in degraded forest patches around villages in the Biosphere Reserve area. Similarly, in the Gulf of Mannar BR, the key island of Krusadai in the BR core zone is under the control of the Fisheries Department, which is carrying a programme of establishing aquaculture practices. Oyster culturing is also carried out on a commercial scale on the island. In the Manas Biosphere Reserve, a seed farm is functioning in an area of 900 ha in the core zone which used to be prime grassland habitat for several endangered species.

However, there are also instances where successful programmes conceived outside the BR arrangement have been meshed into a BR area. For example, the Joint Forest Management (JFM) programme in West Bengal has been launched in the Sundarban BR in collaboration with the Sundarban Development Board and local NGOs. Forest Protection Committees (FPCs) in the area are now protecting mangrove patches in the barren mudflats and barren intertidal spaces between embankments.

Efficacy of development plans

The efficacy of development plans is an important indicator of the BR programme. BRs, by definition, need to fulfil integrated conservation and development objectives. Whether funds and equipment intended to fulfil the development goals actually enhance capabilities of target groups is the key question here. In general, the funds made available by the MoEF for the BR programme have rarely reached target groups because of a general lack of awareness about the objectives of funding both among the implementors and the target groups. In the Nandadevi BR, the Forest Department was provided with vehicles to prevent illegal poaching, but the vehicles could hardly reach the trouble spots due to the mountainous terrain, and poaching of musk deer and illegal export of musk to neighbouring countries still continues from Pithoragarh area. It is also reported that television and VCR sets meant to screen documentary films for awareness creation in the area were actually used by local politicians to show commercial films to bag votes in the elections.

There are other examples of misplaced priorities. Bhotias, the local shepherds in the Nandadevi BR, were randomly provided with fuel efficient *chullahs* which would consume less wood and check deforestation. However, the local people of the area found these of hardly any use; since they needed big fires to tackle the severe cold, which these chullahs could not provide. In the Sundarban BR too, the experiment with fuel efficient *chullahs* largely failed because the local people were given practically no training on how to use them and ultimately, the *chullah* chimneys came to be used as farm implements.

Scientific research

Capacity building and demonstration objectives of Biosphere Reserves may be evaluated through the extent of ongoing scientific research. The Indian Biosphere Reserves have performed fairly well in this regard, when each Reserve is taken separately. However, there has been no attempt to create an integrated information system for the entire network. Also, while major biological or socio-economic studies are going on in many of the BRs, multifaceted research integrating ecological, social and management imperatives seem to be lacking except in the Nilgiri BR where the Kerala Forest Research Institute (KFRI) and the Indian Institute of Science, Bangalore have an active research presence.

Outer links — interaction with the larger economy

BRs should aim at developing systems that enhance positive interactions with the larger economy. A significant area of such interaction is the development of good information on medicinal plant resources. However, Central Institutes entrusted with this job (such as the Central Institute of Medicinal and Aromatic Plants) seem to have no interaction with BR authorities. The Forest Departments too, normally have very scanty information about these resources, and the only source of information is possibly the local collectors. With no mechanism to involve these local people in managing these bioresources, the present trends clearly support the short-term profit making behaviour of commercial interests. In Gulf of Mannar BR, the fishing trawlers from outside countries exploit more fishes in lesser time. Also several demand driven activities like pearl fishing, and export of white and black sea cucumbers as a food delicacy to Southeast Asian countries continues. Similarly, exploitation of seafood like crabs and lobsters continues to supply the demand from countries like Japan.

Negative environmental impacts of activities dictated by the external economy need to be tackled under the BR programme. In the Sundarban BR, for instance, the local people collect prawn in juvenile stages for aquaculture. In the process, other small fish and crustaceans are incidentally destroyed. Furthermore, ponds constructed to store the prawn seeds breach the embankments which are essential for keeping out saline water from the cultivated land. No government agency has so far paid attention to the issue, although a few local NGOs have expressed concern. The basis of BR management needs to be broadened to address these issues.

A related issue is the extent to which BRs create new conflicts or alleviate or accentuate existing conflicts among resource users. In the Manas BR, for instance, a state sponsored seed farm exists in the core zone. This farm largely employs urban people and caters to the demands of urban centres in the Brahmaputra Valley. The local Bodo tribals who live on the fringes are left out of the process, resulting in insurgent tendencies.

Similarly, in Nandadevi BR, excessive tourist traffic around pilgrimage areas creates great pressure on local resources like fuelwood and generates large amounts of solid waste. However, a summary ban on trekking in the core area has hampered the local economy. In this situation, carefully planned ecotourism or ecotrekking could be organised rather than going for a summary ban on trekking, while allowing uncontrolled pilgrim traffic.

Responsive Indicators

A robust programme level evaluation of the Biosphere Reserve Strategy calls for more information with regard to a much wider set of scientific indicators. However, our snapshot view suggests that the system of indicators should be responsive enough to address specific concerns of ecologically handicapped communities such as those facing major conflicts with wildlife.

The following issues could dictate the choice of indicator methodology:

a) Indicators need to be discriminatory at stress and response level, alternatively in the baseline and project scenarios. Ecosystems are subject to varied amounts of stress based on a range of social and ecological factors. For instance, much of the Sundarban BR area was historically subject to severe population pressures due to settlements driven by a revenue-maximising policy adopted by the British government. An indicator of capabilities should be sensitive (discriminatory) to stresses of this kind. It should be able to assess whether the BR strategy has been able to address this specific local condition. As we have mentioned, judging by this criterion, Sundarban BR has failed to reduce man-wildlife conflicts in the area due to lack of employment alternatives (in the slack season) even though statistics of overall employment creation for Sundarban BR give a favourable picture.

b) Development interventions need to improve access to an appropriate resource bundle sustainably across communities. Thus, indicators are to be community- (or user group-) specific rather than aggregative when dealing with resource access. Special attention should be paid to ecologically or socially disadvantaged groups. Local shepherds in the Nandadevi BR are a case in point. These people traditionally depend on their livestock for their livelihood. Collection of medicinal herbs is a secondary activity. They live in a relatively closed society with limited external links. An intervention that aims at meeting a broader conservation objective needs to carefully address community needs such as alternative livelihoods. Our indicator should necessarily disaggregate these communities and their needs. In this case, the intervention — banning of grazing — failed not just in addressing the local livelihood issue but also in taking into account local ecological understanding. For instance, moderate level of grazing maintains herb diversity and contributes to local medicinal practices.

c) Participatory process documentation built into a project implementation plan could generate valuable information on local conflict resolution, innovative cultural practices, etc. Indicators could assess impact of interventions on these issues. It is common for development projects to be planned from above and evaluated from above. Even indices for participation in the project are calculated through limited appraisal exercises planned at higher official levels. What is needed is an in-built Monitoring and Evaluation strategy where local people would be able to continually evaluate the development intervention through participatory processes. Biodiversity Registers could be a possible tool for this. Local people could be involved by teams of local college/school teachers and students or local NGOs in a participatory documentation exercise regarding status of biodiversity, management practices, development aspirations, etc. This process could be repeated for a set of indicators periodically to assess project performance.

The major challenge becomes the use of an adaptive evaluation methodology sensitive to the proximate concerns of stakeholder groups.

The typical logical framework adopted by the World Bank and other donor agencies often misses out an analysis of the appropriate disaggregration level (See Table 1). This paper suggests a modified frame incorporating this need, which should lead to a more responsive evaluation of funding efficacy.

LESSONS LEARNT

Biosphere Reserves are eminently suited to fulfil our obligations under the Convention on Biological Diversity which stresses on conservation and sustainable use of biodiversity and equitable sharing of the benefits flowing therefrom. Biosphere Reserve, as a model for conservation and development, is undoubtedly a viable alternative to the protected area based approach which stresses conservation at the expense of livelihood options of people. However, as our study shows, the BR model needs to overcome several difficulties if it has to be effectively applied. On the one hand, it needs to be integrated with various regional planning processes; on the other, the implementers need to clearly understand its objectives and percolate these down to target groups.

The emergent possibilities in the field of biotechnology have made scientific research and good information management all the more important. As we mentioned earlier, while individual BRs have taken up isolated research programmes, there is no attempt to organise resource data at higher levels. In Costa Rica, for example, the INBIO institution is engaged in fulltime screening of biodiversity of the country's forests and Japan has set up an institute for marine biodiversity prospecting in Micronesia. India is rich in traditional use-related knowledge of various medicinal plants and similar activities ought to be organised as part of the BR programme to take advantage of its megadiversity status.

Promotion of the involvement of local people in management of BRs ought to be another thrust area. As we have mentioned, local people often have a strong ecological perspective on issues like grazing of livestock; this is not accounted for in plans decided by higher officials. Conflicts on resource use, as between Bodos and urban people in Manas BR, need to be carefully addressed in BR plans. For instance, the creation of the Orinoco-Casiquiare BR in Venezuela, covering 83,000 sq. km of rainforest area was a response to concerns of Yanomani and Wekuana tribals regarding development of the area by outside interests. The presidential decree that established this BR states measures to protect the traditional livelihoods of the tribal communities and acknowledges their land ownership rights. The decree also prohibits any colonisation of the area or any other interventions that violate the rights of the communities (http://nativenet.uthscsa.edu/archive/nl/91b/0307.html).

Currently, 356 BRs are designated in 90 countries as part of the international network of BRs. However, participation of a BR in the network is voluntary. Only three out of India's eleven BRs are currently official members of the network. Such networking would be crucial to fulfil the logistic support role of BRs.

The Global Environment Facility with a $2.75 billion replenishment in 1998 is currently emerging as the major funding mechanism for biodiversity. Funding from UNESCO's regular programme has progressively decreased over the years, reaching a modest amount of $300,000 in 1995. The GEF, on the other hand, allocated $600 million to biodiversity during its first (post-pilot) phase (1994-97). The GEF is progressively stressing on funding integrated conservation-development projects as opposed to those based on protected areas. The present funding climate thus favours a renewed interest in the BR model. BR projects thus need to be streamlined to meet the emerging funding criteria and the BR philosophy needs to be embedded in country priorities.

Table 1: Sample logframe for performance evaluation of Biosphere Reserves

Indicator	Class	Dataset/method	Discrimination level*	Performance
Changes in information level	Management capacity	Official records, workplans,	International, national, interviews	Poor by discriminatory local criteria
Incorporation of local practices	Responsiveness	Scientific publications, local knowledge	Specific communities; Specific cultural practices	Poor by discriminatory criteria
Enhancement of entitlements	Resource access	Employment/income data, local knowledge	Specific communities; Bundle of basic amenities	Good in terms of income generation alone, poor by discriminatory criteria
Man-nature conflicts	Resource access	Field reports	Ecologically handicapped groups**	Six of the eight BRs report conflicts
Management plans	Management capacity	Policy papers, work plans	Applicability to community needs	Poor at legal and implementation levels
Scientific research	Capacity-building/ demonstration	Publications, field data	Country, individual BR; research components	Good at BR level, poor at higher levels

*World Bank methodology does not include this in the typical logframe. An appropriate level of disaggregation is often crucial in the interpretation of an indicator.

** Groups exposed to ecological hazards in pursuit of livelihood activities, e.g. a community living on the fringe of a Tiger Reserve and relying on collections from within it.

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PERSPECTIVES ON THE USES OF BIOCIDES: CONSERVATION STRATEGIES FOR THE NEXT CENTURY

Robert W. Risebrough[1]

Key words: India, biocides, DDT, wildlife

DDT has played a critically important role in anti-malarial programmes but future usefulness will be limited by increasing resistance of the mosquito vectors to DDT and other insecticides. In areas of past intensive use, DDT, in the form of its derivative DDE, has depressed the productivity of sensitive species of birds, leading in some cases to their local extinction. In India, environmental levels have appeared to remain below the threshold of chronic harm to wildlife, in part because of lower levels of use and in part because of high rates of loss to the atmosphere. DDT use could therefore continue in the anti-malarial programmes without environmental damage. The longer-term threat to biodiversity and species abundance from the continuing use of biocides, including insecticides, herbicides and rodenticides, in India, is expected to derive from harm to non-target organisms in the form of poisoning and reductions of the biomass that constitutes the food source.

Although there have been tragedies such as the loss of the cheetah (*Acinonyx jubatus venaticus*), and poaching is still a threat to the remaining tiger (*Panthera tigris*) populations, India has maintained a higher density and diversity of wildlife living in close proximity to people than any other nation on the earth, a consequence of the reverence for life inherent in the majority cultures. In spite of increasing human populations and their continuing encroachments into parks and reserves, the biodiversity and abundance of wildlife have remained relatively high during the current period of rapid economic growth. In this expanding economy, India has become not only a major consumer of biocidal chemicals in agriculture and in public health programmes but also a major manufacturer and exporter of these products. The *Farm Chemicals Handbook* 2001 reports that India, with China, is now the world's largest and only source of DDT and, with China, is now the world's largest user of DDT [Anonymous 2001; DDT: 1,1,1-trichloro-2,2-bis (*p*-chlorophenyl) ethane, related compounds and derivatives]. The American Bird Conservancy has reported that India now accounts for about 43% of the global yearly use and a substantial amount of the yearly production of 30,000 tonnes of the insecticide Monocrotophos (also known as Azodrin) (Anonymous 2002), one of the most poisonous chemicals ever sold to the public (Skripsky and Loosli 1994, Hudson *et al.* 1984); its use has frequently caused massive mortalities of birds (e.g. Mendelssohn and Paz 1977, Goldstein *et al.* 1999).

The decision by the Government of India on March 5, 2002, to accede to the Stockholm Convention on Persistent Organic Pollutants will eliminate the use of DDT in agriculture and limit its use in India to the control of malaria and other vector-borne diseases. The Treaty will also end the uses of 8 other chlorinated biocides which, like DDT and its derivatives, move through ecosystems, accumulate in food webs, and pose various degrees of hazard to both humans and wildlife. The era in which these chlorinated hydrocarbon "pesticides" were to have eliminated all vector-borne diseases and created a pest-free agriculture has ended; the once-promising technology had major inherent flaws. But the production and use of large amounts of other insecticides, herbicides and rodenticides, all included here under the label of "biocides," continues, with the specific aims of reducing populations of selected wildlife and plant species that are considered to be injurious to humans.

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A Centenary offers an opportunity not only to look back over the previous century but also to anticipate the next century with the experiences of the past as a guide. This essay will attempt to achieve some perspective on the "pesticide" issue with a focus on India, in part by addressing the significance of the continuing use of DDT in the malaria programmes. The word "pesticide", however, will be avoided; its use overlooks the reality that not only "pests" are killed by applications of these chemicals. Moreover, "wildlife" is defined to include insects and other invertebrates, so many of which have been the subjects of manuscripts published in this *Journal.*

A BROADER PERSPECTIVE

The human species is hardly unique in using chemicals to promote its survival and well-being. Three of the most familiar plant species in India, the tea (*Camellia sinensis*) and coffee (*Coffea* sp.) plants and the neem tree (*Azadirachta indica*), derive their usefulness to man from a complexity of chemicals that do not contribute to the metabolic processes that keep these organisms alive. Rather, they are the instruments of a sophisticated form of chemical warfare in which these and other plant species have engaged throughout their evolutionary history to avoid being eaten. Caffeine and a large number of other chemicals have served this purpose well. Strychnine, an alkaloid from the seeds of *Strychnos nux-vomica*, and rotenone from the roots of *Lonchocarpus* sp. and *Derris* sp. are other "natural" chemicals that have become potent biocides used by humans. An increasingly important group of biocides, the pyrethroids, are variations of the "natural" chemical pyrethrum which is synthesised by *Chrysanthemum cinerariifolium* and discourages its insect predators. Such chemicals are therefore used by both plants and humans for the same purpose.

In turn, biochemical processes have appeared throughout the evolutionary history of insects and other invertebrate plant consumers that metabolised or otherwise inactivated the chemical defences of the plants. The variety of biocidal chemicals used by humans does not yet match the arsenal used by other animals to eat or to avoid being eaten. Within this broader perspective, therefore, we might view the use of biocidal chemicals by humans as a "natural" act, but with critically important qualifications. The use of "warfare" chemicals by other species is highly selective and very rarely harms non-target species. Selective pressures, against the needless expenditure of energy, work to reduce the amounts of these chemical warfare agents to no more than what is necessary. Nature has therefore provided guidelines that humans might profitably follow.

Silent Spring

Not only did this book (Carson 1962) launch the environmental movement, its author has become its Patron Saint. Is this acclaim justified? The chemical industry vilified it for a number of years but appears now to have accorded it a measure of acceptance — it is hardly in the long-term interest of the industry to kill organisms that are beneficial or that maintain the biodiversity of food webs. Nor is it in its longer-term interest to produce products that threaten human health. Moreover, production of biocides that are substitutes for DDT and other chlorinated hydrocarbons has been profitable. Many, however, have criticised SILENT SPRING as "unscientific" or as scientifically flawed (e.g. Ames and Gold 1998). Advocates of DDT use continue to assail it; Ross (2000) has described the restrictions on DDT use as "the unfortunate legacy of the self-styled environmentalists, whose bible remains Carson's SILENT SPRING." If a balanced and scientifically accurate historical perspective on the merits of this book is to be achieved, a task this essay can only begin, these criticisms deserve to be fully and adequately addressed.

Rachel Carson was wrong in attributing the mode of action of the biocides then in use to a disruption of oxidative phosphorylation, the universal process that creates usable energy within the cell in the form of the ATP molecule. Yet she had assembled a vast amount of information and undertook what appears to have been the best possible synthesis at that time, a synthesis no one else was apparently even attempting. Later research was to demonstrate a broader and somewhat different diversity of biocide effects. An imperfect and inaccurate conclusion, which was nevertheless intellectually honest, about the way in which these poisons exert their effects, does not affect the validity of her principal themes that biocides are poisonous chemicals that were being applied in massive amounts to the environment where they were killing many non-target organisms, producing unintended and unanticipated results such as resistance, and posing potential dangers as yet unsuspected.

She was also wrong on the cancer issue, in assuming that the "natural cancer-causing agents" are "few in number" and that most of the modern cancers can be attributed to synthetic chemicals produced by humans. Rather, only a small percentage of the cancers not caused by smoking can be attributed to synthetic chemicals (Ames and Gold 1997, 1998). Apologists have pointed out that completion of the book was a race against her own impending death from breast cancer. Here also, however, she was providing an interpretation of the overall meaning of a considerable body of information about chemicals and cancer. The much larger amount of knowledge about environmental cancers, that has accumulated over the past 40 years, has not supported her interpretation that was based on a much smaller information base. Yet her attempts to assess the significance and to predict longer-term effects of the use and misuse of huge quantities of poisonous chemicals can only be considered as both intellectually honest and socially responsible, values that later environmentalists have not always maintained. Interpretations inevitably change as more information and more data become available.

Her explanation of the low productivity of populations of bald eagles (*Haliaeetus leucocephalus*) that was observed in 1947 in Florida (Broley 1958) and in a sanctuary established for bald eagles on the Susquehanna river [H.H. Beck, pers. comm. to R. Carson (Carson 1962)] was confirmed only some years later: "There is some occupancy of nests by adults, some production of eggs, but few or no young birds. In seeking an explanation, only one appears to fit all the facts. That is that the reproductive capacity of the birds has been so lowered by some environmental agent that there are now no annual additions of young to maintain the race." This explanation has since received full scientific support. The "environmental agent" turned out to be DDE, a derivative of *p,p'*-DDT, the active biocidal component of technical DDT. Its principal effect on sensitive bird species could never have been predicted — alterations of the eggshell structure such that the more contaminated eggs would either break or fail to hatch. Like other organochlorines, it moves readily throughout the global ecosystem; its non-polar character results in its accumulation in food webs, affecting those species at the top of the food webs that are sensitive to its effects. Carson's explanation, derived from the relatively small amount of information then available, could not have been more accurate — and scientifically sound.

Her documentation of the massive mortalities of non-target species, the futility of spreading large amounts of poisons over the landscape, and the inevitable appearance of resistance of the target species to biocides cannot be challenged. Her position as Patron Saint of the environmental movement is secure; imperfect interpretations in the public interest, in response to a genuine problem, have a value that is immune to the attacks of either commercial interests or the inflated egos of scientists defending an imperfect technology that they, to their credit, have helped to build.

HOW BAD IS—OR WAS—DDT ?

The deliberations leading up to the creation of the Stockholm Convention prompted another chapter in the continuing debates on the merits of DDT (e.g. Roberts *et al.* 2000, Smith 2000), with some environmental groups including World Wildlife Fund (Anonymous 1998, 1999a) and the Physicians for Social Responsibility (Anonymous 1999b) pushing for an ultimate global ban on the use of this chemical, with organisations such as the World Health Organization pointing out its continuing value to public health programmes (Kapp 2000), and with many individuals and organisations proclaiming either that the use of DDT has been one of the greatest achievements of human civilization or that its hazards justified an immediate global ban. At best, this essay will be only a modest first attempt at a definitive assessment of the pluses and minuses of a chemical that will — whatever the final verdict — have a prominent place in the history of technology.

Certainly, there is no disagreement that its use was spectacularly successful in the eradication of malaria in many areas of the world. By creating a temporary absence of mosquito vectors while the disease took its course in humans, the cycle of transmission was broken and the *Plasmodium* species responsible for the disease became locally extinct. But malaria has returned with a vengeance to Mumbai (Kamat 2000) and the rest of India (Sharma 1996). Would the eradication campaign in India have been successful, as it was in countries such as Taiwan (Yip 2000), had not the extensive use of DDT in agriculture hastened the inevitable appearance of resistance? Would a more concerted effort of spraying the walls of houses with DDT within a relatively short time period have resulted in success? These are questions for which no adequate answers are available, although it is likely that in both cases the answer would be positive. In any case their relevance to current policy is diminished; in India there is a high degree of resistance to DDT, and to several other insecticides, among the vectors of malaria (Sharma 1999); the current global emphasis in malaria control programmes is on treatment rather than the elimination of the vectors (Baird 2000).

Also, it cannot be disputed that DDT is still being successfully used to control and to eradicate malaria in some areas of the world (Dapeng *et al.* 1996).

The first objections to DDT came after the massive mortalities of birds, that followed its use, mainly at higher doses and particularly in a programme to "eradicate" the gypsy moth *Lymantria dispar* on Long Island in New York State, USA. The gypsy moth is an introduced species that each year has defoliated oak (*Quercus* sp.) woodlands of the northeastern USA. A lawsuit was brought in the 1950s against the US Department of Agriculture by Robert Cushman Murphy and Grace Murphy, to stop the "eradication" programme on the grounds that birds were worth more than the loss of foliage, which usually did not kill the trees, and that the programme was not working as the moths came back year after year. Although lost on technicalities, the lawsuit nevertheless exposed the weaknesses in the "eradication" concept and prompted the beginnings of change in public perceptions of "pesticide" use. So entrenched were these public perceptions that the Audubon Society, the major US conservation organisation at that time, did not support the lawsuit of the Murphys, nor would it provide a pre-publication endorsement of SILENT SPRING (R. Clement, pers. comm.).

The next lawsuit was brought in 1966 by a Long Island housewife, Carole Yannacone, who objected to a fish kill in a local marsh. Ultimately the court decided that it did not have jurisdiction, with no law upon which to base a decision, but the public awareness generated by the case resulted in the ending of DDT use in the local marshes.

In the autumn of 1968, American elm trees *Ulmus americana* were to be sprayed with DDT in the city of Milwaukee, Wisconsin, to combat the Dutch elm disease, caused by the fungus *Ophiostoma ulmi* which is carried from tree to tree by either of two species of beetles, the European elm bark beetle *Scolytus multistriatus* or the native elm bark beetle *Hylurgopinus rufipes*. The disease was then killing the elms over northeastern North America, where it had long been a cherished shade tree; in previous years the programme had killed many hundreds, probably thousands of birds. The Citizens Natural Resources Association, Inc. of Wisconsin, joined by the Izaak Walton League of America, requested a hearing that would determine whether DDT might be considered an environmental pollutant under Wisconsin law, which defines environmental pollution as "contaminating or rendering unclean or impure the air, land or waters of the state, or making the same injurious to public health, harmful for commercial or recreational use, or deleterious to fish, bird, animal or plant life." The hearing was undertaken in a courtroom format, with vigorous and frequently hostile questioning of witnesses. Critically important financial support was provided by the National Audubon Society, which was no longer neutral on the DDT issue.

I was privileged to participate in this hearing, initially to testify on the mobility of DDT, and later on the effects of DDT on pelicans and other fish-eating birds. Conflicts with industry representatives were frequent, and bitter. The species principally affected in Wisconsin were the peregrine falcon *Falco peregrinus* that had become locally extinct, the bald eagle that had almost disappeared, the osprey *Pandion haliaetus* that was producing thin-shelled eggs, and the double-crested cormorant *Phalacrocorax auritus* that was much reduced in numbers. In the state of Wisconsin, the value of these species and of the integrity of the ecosystem was considered higher than the economic benefits of a cheaper insecticide; the Hearing Examiner, Maurice Van Susteren, ruled that DDT met the criteria of an 'environmental pollutant' as defined by the law and its use ended in Wisconsin.

There were no public health issues to be addressed in Wisconsin. Ideology did not intrude on the relatively straightforward scientific arguments that were relevant to application of the law. On the industry side, however, ideological considerations occasionally obscured the defence of economic interests; the questioning of "pesticide" use was considered unpatriotic, seditious and perverse (e.g. McLean 1967).

Later, in 1970-72, the newly formed Environmental Protection Agency conducted hearings in Washington, D.C., to address the question whether the use of DDT should be ended on a national level. More than 100 witnesses participated, representing almost all facets of DDT use and documenting a wide range of environmental effects. Here also, confrontations between environmental scientists and the DDT industry were frequent and bitter. The Hearing Examiner, a retired lawyer with no scientific or environmental credentials, ruled that DDT did not constitute a danger to wildlife or people, but he was overruled by the Administrator, who found that continued DDT use posed an unacceptable potential risk to human health (Ruckelshaus 1972).

The wisdom of this decision continues to be challenged (e.g. Lieberman and Kwon 2002). The decision was supported largely by the possibility that DDT or one of its derivatives might be a human carcinogen, on the basis of rodent studies undertaken by the International Agency for Research on Cancer (IARC) using high amounts of DDT (Anonymous 1991, and earlier reports of the IARC). A vast amount of subsequent research has failed to find a link between DDT compounds and human cancers, including breast cancer (e.g. Adami *et al.* 1995, Ahlborg *et al.* 1995, Wolff *et al.* 2000, Laden *et al.* 2001). Yet this decision by Ruckelshaus in 1972 not to permit a continuing build up of DDT residues in the environment must be considered the only responsible one that could be made at that time in a country with no major problems of vector-borne diseases. It was just too early to make any definitive statement about the carcinogenicity or other adverse effects of DDT on humans; contamination of the global environment could not be quickly reversed if such an effect were discovered. The thinning by DDE of eggshells of a number of bird species, and depression of productivity in many of those species, provided an example of the deleterious effect of a synthetic chemical in the environment, that most likely would never have been predicted from the broadest range of toxicity tests in the laboratory. Similarly, a longer-term subtle but deleterious effect on humans might not be detected until years later. The same argument was used for ending the use of the polychlorinated biphenyls (PCBs), which also were produced in large quantities, and like DDT are mobile and persistent, and are accumulated in food webs (Risebrough and Brodine 1970). In the case of the PCBs, the validity of the argument has been abundantly vindicated; an entirely unexpected effect of the PCBs is a depression of learning capacity of human children exposed to PCBs in the womb (e.g. Darvill *et al.* 2000). Any increase above current levels of PCB contamination in the environment would have disastrous effects on human welfare; the release of large amounts of persistent, mobile, toxic chemicals into the global environment constitutes an experiment with unpredictable results. A policy that would prevent their accumulation is both sound and defensible.

Meanwhile, other persistent chemicals with demonstrated biological activities and which accumulate in food webs are now being detected throughout the global environment; the brominated diphenyl ethers, widely used as fire retardants, are an example (Kuehl and Haebler 1995, Noren and Meironyte 2000, She *et al.* 2002). Fluorinated surfactants, with unknown biological properties, have recently been detected in marine wildlife in concentrations that must be considered "high" (Giesy and Kannan 2002).

The lessons from DDT and the PCBs about the hazards of releasing large amounts of persistent mobile chemicals into the global environment have yet to be learned. Moreover, it is still not possible to conclude that DDE has had no harmful effects in humans. A report of an association between DDE levels and human premature births (Longnecker *et al.* 2001) might be compared with an earlier study of premature births of California sea lions *Zalophus californianus*. Concentrations of DDE in the blubber of female sea lions giving birth prematurely, in 1972 on the southern California island of San Miguel, were eight times higher than in females with full-term births. Yet, confounding factors, such as the possible presence of a disease factor, age, nutritional status, possible contributions by other contaminants and the absence of previous pregnancies, precluded any definitive conclusion that DDE was a contributing cause (Gilmartin *et al.* 1976). The hypothesis that DDE was at least in part responsible, however, remains valid, as does the hypothesis of a comparable DDE effect on humans. Although confounding factors may eventually be shown to be the responsible factors, an association between DDE levels and the duration of lactation of nursing human mothers (Gladen and Rogan 1995) appears to be another probable effect of DDE on humans.

Although solid evidence for an adverse effect of DDT use on human health remains elusive, the evidence for an adverse chronic environmental effect in the form of a depression in productivity of a number of bird species has strong and convincing scientific support. The Environmental Defense Fund, which undertook the legal challenge to the use of DDT in both Madison and Washington, other environmental groups, and individual environmental scientists had built their case against DDT on the basis of the scientific evidence for adverse environmental effects. DDE has been shown to produce eggshell abnormalities in these species, which result in either breakage of the eggs or their failure to hatch; the biochemical mechanism, however, is yet to be adequately described. Experimental studies have produced the same effect with concentrations of DDE that existed in the environment; other environmental contaminants such as the PCBs and methyl mercury produced no effects on the eggshells (Risebrough 1986). Following the national ban on DDT use, and the ending of the discharge of waste DDT into the sea from a manufacturing plant in Los Angeles, recovery of populations of bald eagles in eastern Canada (Grier 1982), ospreys of New England (Spitzer *et al.* 1978), brown pelicans *Pelecanus occidentalis* of California (Anderson *et al.* 1975) and peregrine falcons throughout North America (Cade *et al.* 1988) was rapid. Bald eagles are still unable to reproduce in the contaminated marine environment of southern California (Garcelon *et al.* 1989, Jenkins *et al.* 1994), but elsewhere in North America the environmental levels of DDE are generally now below the threshold for harm.

By the late 1960s, both DDT and PCB compounds were being detected in marine birds at concentrations that were likely to be above or near the thresholds of biological effects (Risebrough 1969, 1971, Risebrough *et al.* 1968). Recognition of the magnitude of this contamination (e.g. Goldberg *et al.* 1971) was a principal factor in changing perceptions about the scale of human activities within a global ecosystem of a finite size. DDT (or PCBs) used anywhere in the world would ultimately move into the global environment. However, in spite, of the earlier interest in global marine pollution, no recent data are apparently available that would indicate the magnitude or direction of current trends.

In summary: DDT played a critically important role in reducing the incidence of vector-borne diseases. Locally it is still effective for this purpose, but since resistance of the insect vectors to DDT continues to increase, its longer-term usefulness is low. Concerns about hazards to human health cannot be dismissed, but these hazards appear to have a lower risk of harm than a vector-borne disease. Its derivative DDE has the unique capacity to depress productivity of sensitive bird species, but only above environmental thresholds of harm. If low-volume use of DDT does not increase environmental levels of DDE to the threshold for the most sensitive species, environmental damage would not occur. Like other biocides, however, DDT may kill many non-target organisms and disrupt local food webs.

DDT CONTAMINATION OF THE INDIAN ENVIRONMENT

Press and internet communications have reported that the manufacturing capacity of Hindustan Insecticides Limited, a government-owned company that is the only producer of technical DDT in India, is in the order of 9-10,000 tonnes/year, that domestic consumption has been 3.5-5 tonnes and that an equivalent amount has been exported in recent years. It has not been possible to verify these figures and they are therefore considered to be estimates only. Data from the US Tariff Commission indicates that the production of DDT in the USA reached its peak in the mid 1960s at about 73,000 tonnes/year. If we assume that half of this was exported, then excluding Alaska, domestic use at that time was about 5 kg/sq. km/year. Indian domestic consumption at a rate of 3,600 tonnes/year would therefore be only 10% that of peak use in the USA, but since the land area of India is 39% that of the USA outside of Alaska, recent DDT use in India has been about 1/4 of peak US use on an area basis. Before considering other factors such as differences in rates of evaporation and loss, environmental effects in India would be expected to be lower than in the USA by a factor of about 4.

On the basis of information on population declines of peregrine falcons from North America and Europe (Hickey 1969) and available information about the worldwide effects of DDE on peregrine falcons (Peakall and Kiff 1979), it can be expected that the black shaheen *Falco peregrinus peregrinator*, the local peregrine race in India, might be the Indian species that would show the greatest depression of productivity and perhaps also a decline in population numbers. As a predator of other birds it occupies the top of the food web. There are apparently no data on productivity or on residue concentrations that would confirm or negate this prediction. Yet shaheens have continued to breed near Mumbai and continue to be seen in the city during the non-breeding season and elsewhere in India (R. Naoroji and L. Pereira, pers. comm.). Although inhabiting a country of relatively high DDT use, this race of the peregrine appears to have escaped the severe effects this species experienced elsewhere in its global range.

The North American bald eagle, feeding primarily on fish, occupies a somewhat lower position in the food web than does the peregrine falcon. Its productivity is, however, depressed at concentrations of DDE 4-6 times lower than the threshold that affects the productivity of peregrine falcons (Nisbet and Risebrough1994, Peakall and Kiff 1979). Although sensitivity to DDE, measured as effects on productivity, varies widely within the genus *Falco* (Fyfe *et al.* 1988), the Pallas's fish-eagle *Haliaeetus leucoryphus*, of the same genus as the bald eagle, is likely to show depressed productivity in response to accumulation of DDE. This species has not bred in Keoladeo National Park in eastern Rajasthan since the 1980s (V. Prakash, pers. comm.), but there are no data to suggest that DDE was a contributing cause.

The relatively few studies of the distribution of DDT compounds in selected bird species (Muralidharan *et al.* 1992, Ramesh *et al.* 1992, Tanabe *et al.* 1998, Senthilkumar *et al.* 2001) have shown that concentrations generally were about an order of magnitude lower than those associated with severe shell thinning and reproductive failures of related species in North America. Concentrations of DDT compounds in three Ganges river dolphins *Platanista gangetica* from the Ganges river at Patna (Kannan *et al.* 1994) were comparable to those in other species of dolphins in other areas of the world, except for the much higher levels that have been recorded in dolphins from California coastal waters (Table 1). Environmental levels of DDT compounds in India appear to have remained below thresholds of harm.

In part, this can be attributed to relatively high mean temperatures. The rate of volatilisation of DDT compounds into the atmosphere increases sharply with increasing temperature (Lloyd-Jones 1971, Risebrough 1990, Racke *et al.* 1997), enhancing their mobility through ecosystems. DDT leaving India, however, enters the oceans, thereby contributing to global contamination of the oceans, and constitutes a part of the DDT that has reached Antarctica.

CONSERVATION STRATEGIES AND POLICIES

When I was on the witness stand at the DDT hearings in Wisconsin in 1968, I was asked if a small amount of DDT could not be used, in Wisconsin, for any emergency purpose without contributing to environmental harm. The answer was "no." Peregrine falcons had disappeared as a breeding species, bald eagles had almost disappeared, the eggs of an increasing number of species were thin-shelled, and alarmingly high concentrations were being measured in marine wildlife. Environmental contamination levels were above the threshold of harm; any additional DDT would have increased the magnitude of damage. Today, except for the marine environment of southern California where bald eagles are still

Table 1: DDT in the blubber of Ganges river dolphins and dolphins from other areas of the world

Species	Locality	n	Date	Growth stage, Sex	Basis[7] Wet/Lipid	DDE[10]	Total DDT[10]	Reference
Ganges river dolphin[1]	Patna.	1	Oct 1991	Immature male	Lipid	- -	29	Kannan *et al.* 1994
	"	1	Jul 1991	Immature female	Lipid	- -	29	Kannan *et al.* 1994
	"	1	Mar 1992	Adult female	Lipid	- -	18	Kannan *et al.* 1994
Spinner dolphin[2]	Porto Novo, Bay of Bengal.	5	Mar 1990 - Jan 1991	Adults, 3 males, 2 females	Lipid	18	32	Tanabe *et al.* 1993
Bottlenose dolphin[3]	Porto Novo, Bay of Bengal.	4	Apr 1990 - Mar 1991	Adults, 2 males, 2 females	Lipid	9	11	Tanabe *et al.* 1993
Humpback dolphin[4]	Porto Novo, Bay of Bengal.	3	Apr 1990 - Mar 1991	3 adult males	Lipid	11	16	Tanabe *et al.* 1993
Striped dolphin[5]	Eastern Tropical Pacific.	14	Nov 1968 - Jun 1976	Adults, 4 males, 10 females	Wet	13	16	O'Shea *et al.* 1980
Common dolphin[6]	Southern California.	3	Nov 1968 - Jun 1976	Adult females	Wet	630	740	O'Shea *et al.* 1980
	Southern California.	10	Nov 1968 - Jun 1976	Adult males	Wet	850	970	O'Shea *et al.* 1980
	Southern California.	2	Nov 1968 - Jun 1976	Adult females	Wet	1,400	1,600	O'Shea *et al.* 1980
	Texas coast, Gulf of Mexico.	5	Jan 1990 - Mar 1991	Adult females	Lipid	3.7 [8]	- -	Kuehl and Haebler 1995
	Texas coast.	6	Feb 1990 - Nov 1990	Adult males	Lipid	37 [8]	- -	Kuehl and Haebler 1995
Beluga[9]	St. Lawrence river.	2	Nov 1983 - Sep 1984	Adult males	Lipid	80	93	Massé *et al.* 1986

[1] *Platanista gangetica*; [2] *Stenella longirostris*; [3] *Tursiops truncatus*; [4] *Sousa chinensis*; [5] *Stenella coeruleoalba*; [6] *Delphinus delphis*

[7] Since DDT compounds are associated with the lipid component of tissues, concentrations in the lipid are generally 125-330% higher than concentrations in the total blubber tissue, depending on the water content of the blubber, which generally ranges between 20 and 70 %

[8] Assumed to be the arithmetic mean

[9] *Delphinapterus leucas*

[10] Parts per million of the wet or lipid weight

unable to reproduce, the response would have to be a qualified "yes," the qualification deriving from an uncertainty about the longer-term trends in the contamination of the global marine environment. As long as environmental levels remain below a threshold of harm to the most sensitive species, any additional contribution of DDT to the ecosystem could not be considered as environmentally harmful. Particularly when in India the use of DDT in agriculture is to end, under the terms of the Stockholm treaty, opposition to the continuing use of DDT for house spraying in the anti-malarial programmes appears to derive from ideological considerations rather than from a pragmatic conservation policy.

The assumption that indoor use of DDT does not result in environmental contamination cannot, however, be supported. Studies in the Brazilian Amazon have shown that local contamination of soils and the food web of a nearby river resulted from the use of DDT to spray the interiors of houses in an anti-malarial programme (Torres *et al.* 2002). Volatilisation into the atmosphere and hence into vegetation, soil, water, etc., and back into the atmosphere, processes that are highly dependent on temperature (Risebrough 1990), are the pathways by which DDT compounds move from sites of application or deposition. A dramatic example from India is provided by the contamination of the soil and of the human population in the vicinity of a DDT manufacturing factory in Delhi (Saxena *et al.* 1987a, 1987b). Yet, on the basis of the argument presented above, DDT contamination resulting from continuing use in anti-malaria programmes in India will not be of environmental concern and need not be a component of a conservation strategy.

Among the other biocides to be banned by the Stockholm treaty, aldrin and dieldrin have done the greatest damage to wildlife (Nisbet 1988). The poisoning of sarus cranes *Grus antigone* in the vicinity of Keoladeo National Park (Muralidharan 1993) is an example from India that was documented, among the probably countless others that were not. These threats will diminish as the uses of the chlorinated hydrocarbon biocides end.

The major concerns in the past about the use, misuse, and overuse of biocides have derived from the effects these have had on the non-target organisms that constitute much of the Indian biodiversity, many of which have been described and discussed in the pages of the *Journal of the Bombay Natural History Society* over the past one hundred years. It is likely that these will remain the principal concerns throughout the foreseeable future. Reductions of the magnitude of these effects on wildlife and elimination of any adverse effects on humans might therefore be considered as the immediate goal; the longer-term goal must be the maintenance of maximum biodiversity. Whereas description and cataloguing of the Indian biodiversity have been a principal activity of the *Journal* over the past century, the maintenance of the scientific basis for the conservation and long-term survival of this biodiversity will surely be a major focus of the next century.

There are as yet very few hard data on the impacts, on populations, of reductions in available food supply following biocide applications. Applications of insecticides generally do not kill only those insects that are considered injurious to humans, but other insects and invertebrates as well, that are the food base for many birds and other vertebrates. Applications of herbicides kill plants that not only provide seed that supports seed-eating birds but also are the food source of many insects. Establishing monitoring programmes that would detect changes over the next century in the abundance of selected birds, other vertebrates, invertebrates, and plants may not initially appear to be an exciting scientific field worthy of participation and support. Yet if the problem is reframed to ask how changes in the abundance of species can be detected and measured, and how such changes can be adequately explained, it becomes a challenge to the best of scientific minds and of all available resources. It is such an approach that is needed, to assess not only the impacts of future use of biocides, but also of climatic change and all other factors that might affect species abundance and biodiversity. Moreover, without such scientifically sound information, it would be difficult to propose and to justify policies that would protect the biodiversity.

The excessive influence of the "pesticide" industry in California on the volume of chemicals used and the ways in which they were applied has been documented in a now-classic book by van den Bosch (1978). In India, economic interests of domestic manufacturers and the need for foreign exchange will inevitably become factors that influence biocide use patterns in both India and the countries to which the biocides are exported. An alert public that is well informed on technical issues is critically important in correcting balances towards the overall needs of society. Available information provided at the present time by the environmental groups, however, is woefully lacking in accuracy. If this essay were to convey any words of "wisdom" and advice, to the next generations that will work to conserve the biodiversity of India, a goal worthy of their effort, these words and advice would be to shed ideologies and to respect the integrity of technical and scientific information.

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PERCEPTIONS OF THE DEVELOPMENT OF WILDLIFE CONSERVATION IN INDIA, HIGHLIGHTING THE PAST QUARTER CENTURY, AND THE INPUT OF THE U.S. FISH AND WILDLIFE SERVICE THROUGH THE BOMBAY NATURAL HISTORY SOCIETY AND THE WILDLIFE INSTITUTE OF INDIA

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Key words: Conservation, partnerships, cooperation, Service, assistance, research, wildlife

The Indian subcontinent has a rich natural heritage that has been largely maintained historically because of the traditional respect for all life forms by the local peoples. Increasing pressures from a rapidly growing human population have brought about deterioration of habitats and elimination of species. These pressures and their consequences have gradually gained more attention over the years, but in the last quarter century, a sea change in the actions and concerns of not only the Government of India but also a number of organisations, have attracted widespread attention. The Bombay Natural History Society (BNHS), a major non-governmental organisation, and the Wildlife Institute of India (WII), a major Government of India institution, are making a difference in this battle and have benefited from the input of international partners such as the U.S. Fish and Wildlife Service (USFWS). Details of the two and a half decade relationship of the Service's contribution to India's conservation movement through the BNHS and WII are provided, reflecting the benefits of long-term commitment and working together for India's wildlife heritage.

Introduction

What we know as the present-day Indian subcontinent is a diverse landmass with a rich natural fauna and flora where some of the world's earliest known human civilisations flourished over 5,000 years ago. There are signs that these early civilisations not only recognised and used the rich, natural biological diversity around them, but developed views and policies governing use of these resources mirrored in their sacred writings, the Vedas and Upanishads. These teachings on reality and morality linked to the five elements of nature, "earth, water, fire, air and ether," laid down over three millennia ago, are recognisable today and parallel modern-day thinking on ecology and ecological relationships.

The legacy of recognition of, traditional respect for, and protection of, all life forms by the peoples of India, has resulted in the maintenance of a rich natural heritage. This legacy was also bolstered by the actions of royalty such as Emperor Ashoka, who created reserves of forests and issued edicts on the values of forests and wildlife, describing acceptable behaviour, and prohibited activities which could damage renewable natural resources. While the forest resources were often subsequently used by the kings and their guests for hunting and were off limits to others, their value as protected areas has survived to the present, as many of the former royal preserves now form the bulk of the national parks and conservation areas network.

Since the last part of the 19th century and early part of the 20th, many of the remaining patches of forest and rangeland came under the administrative hand of State Forest Departments established under the British Raj for the primary purpose of managing them for forest produce, particularly timber. Despite the difficult transition during the post-independence period and the desperate need for resources from a rapidly growing human population, the major wild land resources represented in the forest preserves were

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able to survive because of the Forest Department establishment.

Concurrent with the Government's actions to more formally protect and manage India's forests, the emergence of non-governmental interests, in the late 1800s, to focus attention on other components of the biological realm was an interesting phenomenon. Among the first of these groups was the Bombay Natural History Society (BNHS) which championed the study of natural history in all its forms. Added to the more scientific studies conducted by the BNHS, the writings of colonials, wildlife observers, shikaris (hunters), and foresters began to reveal the marvels of India's wildlife.

The achievements of the BNHS over its first century have been documented elsewhere. Likewise, the importance of foresters, the evolution and management of wild lands, the institutional description and linkage to wildlife and wildlife management has been widely chronicled. Despite these advances, gaps between information on wildlife and their habitats and management responses by the Forest Department remained great.

In the late 1950s and early 1960s, India's wildlife scene started to pique the interest of the international community. One of the earliest ventures was what became a decades-long relationship between the BNHS and the United States' Smithsonian Institution, focusing on the study of birds. Dr. George Schaller of the New York Zoological Society ushered in a new era with the pioneering study of chital and tiger at Kanha National Park, which employed some recently evolving techniques, merging scientific method with the behavioural study of animals and their habitats.

The 1969 IUCN General Assembly, held in New Delhi, could perhaps be viewed as a watershed for the subsequent events that triggered multiple actions affecting the wildlife conservation movement in India — a chain of events perhaps unparalleled anywhere else in the world. This meeting brought together international conservation leaders and conservationists in India, including a small group of influential Indian businessmen, academicians, foresters and politicians (chief among whom was the then Prime Minister, Indira Gandhi). Problems were discussed, the plight of the tiger was highlighted, and recommendations were made.

The key to the future development and implementation of recommendations from the 1969 meeting was the dedication and determination of Mrs. Gandhi. In 1970, a 6 month duration course in wildlife management was initiated in the Indian Forest Research Institute (FRI) for in-service Forest Officers, the first such course devoted specifically towards wildlife. With the full support of Mrs. Gandhi, the Wildlife (Protection) Act was enacted in 1972. Under this landmark legislation, wild animals and birds were given protection through the creation and establishment of wildlife advisory boards, hunting regulations, sanctuaries, national parks and protected areas, wildlife officer position, policies on trade and commerce in wild animals and animal products, and a list of protected species. In 1973, Project Tiger was launched, and eight reserves were designated specifically as tiger reserves.

At the request of the Government of India (GOI), the Food and Agriculture Organization (FAO) of the United Nations Development Programme (UNDP) sent a consultant to India in 1974 to assess the crocodile situation and recommend a programme for crocodile farming. The relationship with FAO led to a number of visits, creation of a captive breeding facility at Hyderabad, a long-term restoration programme for gharial and other crocodilian species, and a major contribution to what later became the Wildlife Institute of India (WII).

In 1976, India's Constitution was amended to allow the states to legislate forestry and wildlife matters within their jurisdictions.

In the mid 1970s, the scene was set for the entrance of another, perhaps unlikely, international player, the U.S. Fish and Wildlife Service (FWS). Over the next quarter century up to the present, the FWS has been engaged in a major wildlife conservation programme with the GOI. This programme, facilitated through local institutions such as the BNHS and the WII, has influenced and, hopefully, productively altered the organisation and application of wildlife research and management in India and the surrounding region. It is recognised that major milestones were occurring due to actions taken at the highest levels of the GOI. A variety of other activities were also going on, some as a result of the major events, some as catalysts for these events, and some that came about synergistically because of FWS input.

U.S. Fish and Wildlife Service and its Mission

As the principal U.S. Federal agency responsible for conservation of wildlife, the FWS has a mission to promote fish and wildlife conservation and species enhancement, both inside and outside U.S. boundaries. In 1973, a special directive was given to the FWS with the passing of the Endangered Species Act (Public Law 93-205). The Act not only charges the FWS to determine the status of threatened and endangered species worldwide, but also allows U.S. assistance to be offered to foreign nations for the development and management of programmes necessary or useful for threatened or endangered species conservation. While the drive behind FWS's international programme is conservation of endangered species and their habitats, it was recognised that the best way to proceed would be to engage and help existing local institutions in other countries strengthen their abilities and skills. An approach was developed that sought out conservation-oriented projects, focusing on research, management, education and training, which could be addressed by local institutions. By linking with various U.S. organisations that could provide the technical expertise not available with FWS and/or additional financial or other administrative or technical support, the FWS was able to marshal finances, technical expertise, and logistical support that have made permanent contributions to a multitude of issues.

FWS and the BNHS

Fortuitously, early FWS engagement with the GOI in the late 1970s was directed towards BNHS, not only because of its pre-eminent position and long history in facilitating bird studies in the Subcontinent, but because it was the only major organisation in India at the time, with technical personnel experienced in natural history research. Spirited by the leadership of Dr. Sálim Ali, the BNHS developed several multi-year project proposals for Indo-US cooperation. The first of these major projects to be endorsed by the GOI was a 5-year effort starting in 1979 to monitor movements and habitats of birds. This was quickly followed by two other 5 year projects in 1980, the first an ecological study at what is now Keoladeo National Park and the second on the ecology of the Asian elephant and great Indian bustard.

To date, the FWS has supported 16 major multi-year conservation-oriented research projects with the BNHS, covering 68 project years and including studies on Bengal and lesser floricans, birds of prey, wolves and blackbuck, hill stream ecology, wetland ecology, grassland ecology and many others. Each project is conservation-oriented, implemented by the BNHS with local personnel, has training as an important component, and is done in conjunction with the local state government (Forest Department). The focus is to arrive at practical management options in order to address resource issues and make some permanent contribution to the knowledge base of the country.

Besides the hundreds of peer-reviewed scientific publications produced by these projects, nearly 70 young and emerging Indian scientists have got their start or added to their experience through participation in various FWS supported projects. A total of 27 researchers of the BNHS obtained their doctoral degrees, with many more obtaining M.Sc. degrees, while working in FWS funded projects. Several of these wildlife scientists now play crucial roles in the wildlife research and conservation scenario in India.

A number of projects, while fulfilling their original objectives, often created new questions to be asked, and were either extended or reformed into new proposals. The original 5 year avifauna project was extended to 7 years and spawned two subsequent projects, one 5 year project on bird migration and a 3 year bird banding project. The original 5 year project on the hydrobiology of Keoladeo National Park was extended to 10 years and became one of the most comprehensive ecological studies of an ecosystem in Asia. The Birds of Prey project gave rise to 3 additional studies, and so on. This is how science works. Questions are posed as a hypothesis, then tested to see if the hypothesis works. Along the way all kinds of new questions and information arise.

The full impact of these projects with the BNHS, as well as other projects supported by the FWS with other organisations, is seen in the ecological approach they brought to all studies of species and their habitats. Species were no longer viewed as inanimate objects to be studied without context, but as parts of dynamic natural systems that function or do not function in an interdependent manner. If one part of the system is affected, the effects are generally felt in the rest of the system. Indian wildlife scientists were becoming recognised internationally for their ground-breaking work.

A more complete treatment of the BNHS/FWS cooperative partnership in these long-term projects can be found in Anon. (2000) and Ferguson (2002), including lists of publications, theses, project reports, presentations, and a list of the biologists in their present positions who worked in the BNHS/FWS projects.

Besides the FWS support to the many long-term BNHS conservation research studies, the partnership was further strengthened through a variety of other activities which have fed back into India's conservation movement. FWS has facilitated the participation of BNHS personnel in international scientific meetings to present findings from project related research. This not only provides them with the opportunity to disseminate information on India's natural systems to the international community, but also provides them with experience in representing India, builds self-confidence, and helps them make contacts with potential cooperators and collaborators.

The FWS has also provided opportunities for BNHS scientists to visit American and other foreign institutions and field sites for training, interaction with scientific peers, making contacts and confidence building. These opportunities invariably serve to open minds and present alternative approaches to problem solving and ways to do things.

Top U.S. and European wildlife biologists, managers and administrators have been sent to India by FWS for interaction and information exchanges with BNHS colleagues. Many of these relationships have blossomed and endured for lifetimes, creating new opportunities and exchanges between personnel and institutions.

Believing in the need for a good library and reference collection of scientific information, the FWS has attempted to maintain a flow of scientific literature to the BNHS' main reference collection in Mumbai, as well as to individual scientists at their field sites upon request. A rough estimate of the number of such books, publications and environmental education materials would number in the thousands.

Joint efforts with the BNHS on other activities such as environmental education and public awareness have also created multiple effects. The 1983 publication of A PICTORIAL GUIDE TO THE BIRDS OF THE INDIAN SUBCONTINENT arose out of the recognition that good illustrations of birds were fundamental for identification and field observation and no single-volume publication existed that depicted all 1,200+ species of the Indian subcontinent. Beginning with an effort in 1979, the FWS and BNHS persevered in this first attempt to include 1,241 species in a one-volume bird guide that could be taken to the field. John Henry Dick, the well-known American bird painter, provided the 106 illustrations free of charge, as did the authors of the text, Drs. Sálim Ali and S. Dillon Ripley, as a tribute to the seminal work of the BNHS in raising public awareness in natural history and nature conservation.

With financial assistance from the FWS, this publication was offered to the public on a non-profit basis, in order to assure its widest possible distribution and diffusion of knowledge concerning India's rich ornithological heritage among low and middle income groups, among government and private scientific, cultural and educational institutions. The guide has become a mainstay in the BNHS publication offerings, with repeated reprinting to meet public demand, and enabling well-informed citizenry to participate in the appreciation and conservation of wildlife and its habitats, and hence, in the preservation of a healthy natural environment. Proceeds from sales of the book also help support the production of other BNHS publications aimed at creating awareness of our natural world.

1983 was highlighted as the centennial year of the BNHS. A year-long series of events was scheduled to suitably mark the occasion of this venerable institution's 100th birthday, culminating in an international seminar in Mumbai. The FWS supported the participation of 12 representatives from U.S. scientific institutions and universities, with prior experience in India, to attend the seminar and present results of their work, to add to the asset of growing data on the country's biodiversity. The FWS also invited representatives from the BNHS on a U.S. tour to promote the centennial celebration, disseminate information on BNHS activities and objectives, and attract a wider membership network. The BNHS group was led by its President and charismatic leader, 87 year old Dr. Sálim Ali, and included Mr. J.C. Daniel, Director and Curator, and Mrs. Dilnavaz Variava, a member of the BNHS Executive Committee. Making appearances in Washington, DC, Chicago and Baraboo, Wisconsin, the group made presentations, passed out literature, signed up new members, were fêted at various functions, and received funding donations.

One unusual, but significant action which occurred during his time, may have extended Dr. Sálim Ali's productive years. For many of his later years, the Old Man (as he was affectionately called) suffered from a hearing problem, which became so severe that it had become embarrassing for him to appear in public fora as he had difficulty hearing questions, and carrying on meaningful conversations. Though equipped with hearing aids, they often seemed to be more bothersome than helpful and BNHS requests for new batteries became a frequent call to the FWS. Concerned that this hearing impairment would detract from the effectiveness of the U.S. visit, Mr. Daniel confidentially asked the FWS to take the Old Man to a hearing specialist soon after arrival. The Old Man was tested and custom fitted with top-of-the-line hearing aids despite his truculence and unwillingness for this bother. Secretly paid for by donations from a number of U.S. admirers, the hearing aids — which the Old Man decided he liked when they allowed him to hear the calls of birds — remained a mystery to him as to how they came about. The rest of the U.S. tour was a success with the Old Man avidly interacting with his host, returning to India and actively pursuing his work for another four years until his death in June 1987. Prior to his death, he was honoured with an appointment to the Rajya Sabha (Parliament) by the Prime Minister in 1985, and used this platform to effectively raise the cause of conservation to the highest levels of the government. It is conceivable that his improved hearing helped serve this mission more effectively.

Not to be overlooked, is the effect the BNHS/FWS long-term conservation projects had, on the growth and staff training of Indian wildlife institutions, particularly the BNHS and its offshoot, the Sálim Ali Centre for Ornithology and Natural History (SACON). Early on in the BNHS-FWS relationship, concern was expressed by the BNHS directorship that the projects were serving as excellent training vehicles for young biologists, but due to the "soft money" nature of their support, the BNHS had little or no ability to retain the best of these personnel once the projects came to an end. Several proposals addressing this problem were put forward to the GOI for consideration. The main objective was to create a mechanism within the BNHS structure to provide positions and work for the qualified project biologists. Unfortunately, the GOI never saw the same view as that proposed by the BNHS. The concept changed and energies were directed into a somewhat different channel that eventually led to the creation of SACON. Basically, the core staff from the BNHS ecological study at Keoladeo National Park moved to Coimbatore and formed the new research centre at Anaikatti. SACON continues to be led by a former BNHS researcher from the Keoladeo ecology study and employs a number of former BNHS staff and 'graduates' from the cooperative projects.

The FWS support for the BNHS continues to the present and BNHS continues to hold its pre-eminent position in studying, reporting on, and generating conservation actions for India's natural heritage.

FWS AND THE WII

As noted earlier, it was not until 1970 that formal instruction in wildlife management was offered through the Forest Research Institute (FRI) at Dehra Dun. Five years later, following some initial visits by an FAO consultant, FWS was requested by FAO to consider a request to train several Indian wildlife personnel in the U.S. Lack of funding prevented any actions at that time and it was not until 1980 that the FWS had much direct interaction with the programme that would one day become the WII. Perhaps the event that set the stage for future FWS involvement in India, from a formal standpoint, was the adoption of wildlife as a "High Priority" area of cooperation at an India-U.S. Joint Sub-commission on Science and Technology meeting in Washington, DC, in June 1977. The sub-commissions were high-level mechanisms to facilitate bilateral cooperation between the two countries. Subsequent bilateral fora continued to endorse this cooperation and foster a programme involving a broad array of interests. This mechanism has proved highly valuable in providing a forum where FWS, as a U.S. governmental agency, had access and a working relationship with the appropriate Indian governmental agency, in this case the Ministry of Agriculture. Discussions and training for serving wildlife conservation needs became a two-way street.

In an attempt to encourage India to become more networked into the global conservation community, the FWS sent a CITES (Convention on International Trade in Threatened and Endangered Species of Fauna and Flora) team to India in 1979 to discuss CITES implementation requirements and to review the agenda of the upcoming Second CITES Conference of Parties (COP) in Costa Rica with GOI officials. The GOI Joint Secretary, Ministry of Agriculture (Forests and Wildlife) attended the Costa Rica COP. The FWS provided support for the GOI Joint Secretary to attend the CITES Technical Meeting in Bonn in 1980, whereupon India officially joined CITES.

In the same year, 1980, at the GOI request, FWS sent two specialists in wildlife capture, immobilisation and radio tracking techniques to India to conduct training for Project Tiger personnel, representatives from WWF-India, and students from the wildlife classes at Dehra Dun.

Accompanying the U.S. technical team was a cinematographer who recorded the capture and immobilisation techniques on video. Copies of the videos were then made available to a number of Forest Department and Park offices as well as at the FRI, Dehra Dun. They have served as important training aids for many years. This activity was followed by the visit of a team of two FWS wildlife veterinarians to the FRI and the IVI facility at Izatnagar to present classes on wildlife diseases.

In 1981, India hosted the Third CITES COP in New Delhi. The FWS provided financial support for 15 participants from other countries and assisted with other administrative costs. With this meeting, India began several years of leadership in Asia on CITES issues. Also in 1981, India promulgated the Forestry Conservation Act which required permission of the Central Government before any forest land could be diverted to any non-forest use. India adopted the World Conservation Strategy, and joined a number of other International Conventions calling for global preservation of endangered species and their habitats — Wetland (RAMSAR) and Whaling in 1981, Migratory Species (BONN) in 1982, and the Indo-USSR Treaty on Protection of Migratory Birds in 1984.

During this period, Dr. Sálim Ali was pleading the case for more trained Indian biologists in all aspects of wildlife biology and management. This call translated into a month-long workshop on wildlife management techniques at Kanha National Park in January 1982. Sponsored by the FWS, the GOI, and the Madhya Pradesh Forest Department, the goal was to transfer wildlife ecology, management theory and techniques to 60 forest officers and biologists from Central and State Governments, universities and non-governmental wildlife organisations in India. Also present were representatives from Bhutan, Nepal, Pakistan, Sikkim and Sri Lanka. They gathered with 25 senior U.S. and FAO wildlife biologists and the same number of Indian foresters. The instructional material was converted into book form, distributed widely to all participants, and made available to a wider audience at a nominal cost. Some of the present WII curricular content resembles the syllabus of the Kanha workshop and many of the participants established important personal and professional links with their colleagues in India and abroad.

The concept of establishing a training school focusing on wildlife at the national level had been building up for some time. Recommendations and preliminary plans were formulated by the UNDP/FAO specialists and a draft plan was circulated at the Kanha Workshop. The Kanha Workshop proved to be a major catalytic action to the movement to create such an institute and helped decide on its eventual location.

Concurrent with the creation of the WII, there was a push to separate the administration of wildlife management from its existing position under the Forestry Department in the Ministry of Agriculture to a more independent position. Advocates strongly felt the need for a separate Ministry if wildlife was ever to get the attention it deserved. A high-level committee was commissioned in 1980 to study the matter and make recommendations to the Prime Minister. This culminated in a complete re-organisation of the Central Government's administration of natural resources, resulting in a new Department of the Environment which formally became the Ministry of Environment and Forests in 1985. In the process, wildlife was also separated from forestry, with the Forest Wing being headed by the Inspector General of Forests, and the Wildlife Wing headed by the Additional Inspector General of Forests (Wildlife). The newly created WII answers to the Additional Inspector General of Forests (Wildlife).

The charge of the new WII was to operate training courses for foresters in wildlife management and conduct field research to help formulate priorities and guidelines for wildlife conservation. Despite challenges such as the lack of trained personnel for faculty positions, no organised curricula for its training programmes, no structural facilities for housing, and no precedent for breaking out of the insularity of the traditional education system, the organisers and planners moved steadily forward. A portion of the FRI at Dehra Dun was set aside for the WII programme. On May 22, 1982, the WII formally came into being as an autonomous body situated at Dehra Dun. With the UNDP and the GOI sharing the costs of the project, Mr. V.B. Saharia (a Forest Service officer in charge of the Wildlife Diploma Course at the FRI) was designated Acting Director for the new Institute with Dr. John Sale, formerly assigned to the UNDP/FAO crocodile project at Hyderabad, as the FAO Chief Technical Advisor.

In the next five years, a permanent Director, Mr. Hemendra Panwar, was selected. The positions and criteria for faculty were developed and staff selected, the Government of Uttar Pradesh donated land for a new campus, and plans for a new campus were designed and construction initiated. State foresters began receiving more specialised training in wildlife subjects.

In October 1988, the FWS and WII entered into a 5 year cooperative arrangement to train WII faculty in modern research techniques and provide equipment for use in wildlife training and research, including advanced computer hardware and software. Endorsed by the Governments of India and the U.S. under the Indo-U.S. Sub-Commission on Science and Technology, this innovative project has served as an excellent example of what a small bilateral technical development programme can achieve.

There were 12 subject areas originally decided upon, in wildlife ecology and management, but only 10 were dealt with in detail. The remaining two were not developed as full-fledged independent programmes. The programmes initiated included:

Wildlife in Managed Forests
Field Research Methods
Interpretation and Conservation Education
Geographic Information Systems
Systems Analysis
High Altitude Ecology
Wetland Ecology and Management
Wildlife Health
Animal Damage Control
Library and Documentation

Represented in the group of U.S. scientists, eventually totalling 33, who participated in this programme to transfer technology, was expertise from the FWS, U.S. Forest Service, National Park Service, a university and the private sector. Each expert stayed in India from 1 to 3 months and then hosted their counterpart for varying lengths of time during a study tour in the U.S. Under the programme, eighteen WII faculty members, including the Director and project nodal officers, visited scientific institutions, protected areas and other field locations in the U.S. to get acquainted with U.S. training programmes and management techniques. A final component of the exchange was a ‘show and tell’ workshop in India by the Indian and U.S. counterparts to demonstrate to WII faculty and other organisations and universities what was learned in the transfer.

Besides the wildlife courses for foresters developed at WII which included a 3 month Certificate, 10 month Diploma, and a number of 1 week specialised Capsule Courses, its premier programme is a 2 year M.Sc. course to foster original wildlife research and enquiry, often independent of the needs of the government. As a further reflection of the intellectual expansion, WII hosts a number of post-graduate Research Scholars from cooperating universities to carry out original field studies on subjects of mutual interest. The consequences of this movement away from the didactic, resource exploitative, hierarchical approach to a questioning, academically rigorous, independent and dynamic approach to wildlife research, cannot be overstated.

With the output of about 20 Diploma, 14 Certificate, and 75 Capsule Course participants each year, besides the 7 M.Sc. and 25 post-graduate Research Scholars at various stages of their studies, the WII had a tremendous impact in providing a direction and mass to the wildlife movement in India in the early 1990s. The WII/FWS project has been immensely successful in achieving its objective of facilitating the development of WII and its faculty in its formative stages. An important by-product has been the establishment of formal as well as informal scientific information exchange relationships between the WII faculty and a large number of research, training and management institutions and agencies in the U.S.

When the Indo-U.S. project between the WII and FWS was completed in June 1994, a second phase was approved, in 1995, to run for another 5 years. The second phase was envisaged to consolidate the gains obtained thus far and expand the application of modern wildlife research and management techniques. Phase II was made up of 7 specific projects on management oriented biodiversity research and on developing laboratory and field technology and curriculum, conducted by Indian scientists with the support of U.S. scientists.

The 7 projects under Phase II were as follows:

1) Identification of potential areas for conserving biodiversity in the Indian Himalaya.
2) Evaluation of Panna National Park in Madhya Pradesh with special reference to the ecology of sloth bear.
3) The relationships among large herbivores, habitat and humans in Rajaji-Corbett National Parks.
4) Impact of fragmentation on the biological diversity of rainforest small mammals and herpetofauna of the Western Ghat mountains, south India.
5) Establishment of an Indian Cooperative Wildlife Health Programme.
6) Establishment of a wildlife forensic capacity at the WII.
7) Planning and development of interpretive facilities in selected protected areas in India.

The WII and the FWS remained the main collaborating agencies under this programme. Several of the projects were extended for an additional year. All are essentially completed as of date, although the overall programme is not yet formally completed. Several U.S. and Indian organisations were also involved in the completion of the programme, including the Indira Gandhi National Forest Academy (IGNFA; formerly FRI), Dehra Dun, Sálim Ali Centre for Ornithology and Natural History (SACON), Coimbatore, and 4 veterinary colleges.

The results from this collaborative phase are not yet all in. But it is clear that a long-term professional relationship has been established between WII and FWS. The programme has fostered similar relationships with other major conservation agencies such as the USDA Forest Service, the U.S. National Park Service, the U.S. Geological Survey's Biological Resources Division as well as several universities. The programme has enabled WII faculty to develop professional links with a host of scientists and institutions around the world.

Although the collaboration with FWS was designed to provide the most useful modern technologies relevant to Indian wildlife work, the more lasting legacy may be the inculcation of problem solving capabilities employing a scientific method, and the opening up of the WII to take up an important role in the global conservation scene. WII is now recognised not only in India, but also internationally, as a major centre for training and research in wildlife conservation in Asia.

I would like to conclude by saying that the FWS is proud of its role in helping further the cause of wildlife conservation in India.

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CHRONOBIOLOGY, ECOLOGY AND BEHAVIOUR OF SOME INSECTIVOROUS BATS OF SOUTHERN INDIA

(*With twenty-three text-figures and one plate*)

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Key words: Insectivorous bats, chronobiology, ecology, ethology, echolocation, breeding cycles

This review describes the experiments and results of our work with six species of insectivorous bats, inside natural caves, in open spaces and in the laboratory, performed by my students and me, in the Department of Animal Behaviour and Physiology, School of Biological Sciences, Madurai Kamaraj University in the two decades from 1975-1995. We had worked out in detail the behavioural expressions of biological clocks in four species of locally occurring insectivorous bats: *Taphozous melanopogon*, *T. kacchensis*, *Hipposideros speoris*, and *Rhinopoma hardwickei* and the activity/roosting patterns of colonies of these bats in their habitat. Working at a depth of 40 m in a natural cave, we discovered that there is mutual social synchronisation of the circadian rhythm underlying the exodus flight of a colony of *c.* 600 *Hipposideros speoris* bats around the local sunset time. The circadian rhythm in the flight/rest activity of a solitary bat in a solitary cave without other conspecifics ('social informers') free-ran. We also report here results of experiments with *H. speoris* showing that daylight dimmer than starlight (0.0001 to 0.0006 lux) streaming into a cave for *c.* 90 mins could entrain their circadian rhythm. *H. speoris* is very sensitive to light, and light flashes lasting only 0.0625 msecs could shift the phases of the circadian rhythm. The spectral sensitivity of the photoreceptors in *H. speoris* indicates that they have colour vision. The Indian false vampire *Megaderma lyra* echolocates prey (frogs) by 'listening' to prey-generated noise on land (passive mode) and by active echolocation of the frogs in water (active mode). The eyes of most insectivorous bats are very small and are unlikely to participate in vision in the darkness of the night. It is suggested that eyes may participate in detecting dawn, sunrise, dusk and sunset, thus measuring daylength over the seasons of the year. There is annual breeding periodicity in *Hipposideros speoris*. There are 4 distinct breeding cycles in *Pipistrellus mimus*, the female giving birth to twins each time, making it the most prolific breeder among Chiroptera. Many of the observations reported here were first reports of their kind when they were made and published. The ecology of the day roosting sites, place fidelity and social interactions of insectivorous bats are fascinating facets that deserve to be investigated further.

INTRODUCTION

Bats, like rodents, are the largest group of mammals in the world with 1,001 species (Mickleburgh *et al.* 2002) and wide zoogeographical distribution. They can fly thousands of kilometres to inhabit remote islands in the Pacific and the Indian Oceans, live and flourish in all habitable regions of the earth. The Latin name for bats is Chiroptera which means hand-winged, as the forelimbs are modified into simple wings. There are two sub-orders: Microchiroptera (insectivorous bats) and Megachiroptera (fruit-eating bats). Microchiroptera are found in every continent except the Arctic and the Antarctic, whereas Megachiroptera (about 175 species, all belonging to one family Pteropodidae) are confined to Africa, Asia and Australasia. The fruit-eating bats have very large eyes and excellent eyesight, which helps them to find their way and their food in the dark; in contrast the insectivorous bats which rely almost exclusively on echolocation for navigation and foraging, usually have small eyes and very poor eyesight.

The world around us in the tropics is a fascinating place after sunset. There is swarming

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of myriad insects (mostly Lepidoptera, Diptera, Coleoptera and Orthoptera), the air has the fragrance of the flowers which open only at night to their pollinating agents, there is the alluring smell of ripening fruit too. This nightly world is the arena of bats, metaphorically called 'the birds of the night'. The insectivorous bats, without competition from birds, all of which (with a very few exceptions like nightjars and owls) are day active, crop the rich fare from this sea of insects on the wing. The power of flight and ability to echolocate prey are contributory factors for the evolutionary success of insectivorous bats.

G. Neuweiler (Zoologisches Institut der LMU, University of Munich) and his students and the dedicated group of bat researchers at the Department of Animal Behaviour & Physiology, School of Biological Sciences, Madurai Kamaraj University (MKU), Tamil Nadu, undertook a series of experiments related to field ethology, neurophysiology and chronobiology of nine species of echolocating bats of the Madurai region (9° 58' N, 78° 10' E). Neuweiler (1984) has summarised the findings of his team and reported that the insectivorous bats of Madurai foraged in three modes: 1) Surface gleaning, 2) Foraging within foliage, and 3) Open air foraging. Neuweiler elegantly demonstrated that the constant frequency/ frequency modulation (CF/FM) features and the bursts or train of 150 to 250 ultrasonic pulses per second emitted by the bat species while hunting, adaptively varied according to the mode of foraging and topographic features of the feeding habitat (Neuweiler 1984, 1990, Link *et al.* 1986, Marimuthu and Neuweiler 1987).

One of the most spectacular sights coinciding with the sunset in many parts of the world is the exodus flight of huge colonies of bats from their caves. In Bracken Caves in Central Texas, people assemble at sunset to see millions of free-tailed bats *Tadarida brasiliensis mexicana* stream upwards out of the cave for minutes on end. I noticed the same phenomenon when I accompanied my students to cave sites in Madurai when colonies of *Taphozous melanopogon, T. kachhensis, Hipposideros speoris, Tadarida aegyptiaca, Megaderma lyra* and *Rhinopoma hardwickei* flew out of their caves, evening after evening, within minutes of sunset, like cloudbursts. This 'emergence by coup' obviously is a collective behavioural expression of the perfect synchrony of the biological clocks of members of the bat colonies. This was the genesis of my interest in investigations on physiology of timing in various activities, chronobiology, and ecology of the insectivorous bats of Madurai. A study of the literature on the subject revealed that a few people had indeed reported a daily periodicity or circadian rhythm in insectivorous bats of Europe (DeCoursey and DeCoursey 1964, Erkert 1970, 1976, 1978, Laufens 1969, 1973, Voute *et al.* 1974) and the USA (Menaker 1961, Rawson 1960), the earliest of them being Griffin and Welsh (1937). Griffin had discovered the phenomenon of acoustic tracking of prey by insectivorous bats, and famously coined the term 'echolocation' (Griffin 1958). Most research effort in India on bats has been on taxonomy and embryology, contributions to the latter made mostly by M.A. Moghe, A. Gopalakrishna and colleagues (Gopalakrishna 1949, 1950, 1955; Moghe 1952, 1958). Therefore my students and I decided to concentrate on experimental studies of circadian rhythms, and field ethology observations on breeding cycles, ecology and the foraging strategies that these bats employ. There was no scientific information at all on biological rhythms of tropical bats in literature, except the observations of G. Neuweiler on the onset of activity in a colony of flying foxes in Madras (=Chennai) and dates of parturition (Neuweiler 1969). Brosset's papers (Brosset 1962a, b, c, 1963), first brought to my attention by Mr. J.C. Daniel, served as an excellent introduction to the bats of India.

The present review describes the experiments and results of our work, in the laboratory, inside caves and in the open, carried out by my students and me from 1975 to 1995. We worked on the behavioural expressions of biological clocks in four species of locally occurring insectivorous bats: *Taphozous melanopogon*, *T. kachhensis*, *Hipposideros speoris* and *Rhinopoma hardwickei*, and have accumulated, as a result, the largest database on biological clocks of bats anywhere. This report includes data obtained in the laboratory on free-running flight activity rhythms in these bats and their responses to light pulses and monochromatic light pulses.

Terminology and Abbreviations

In the interests of readability, much of the jargon of 'chronobiology' has been left out of this essay. Some essential abbreviations and symbols, standardised by Aschoff *et al.* (1965), and since then much in use are given below.

LD: light/dark cycle

LL: continuous light

DD: continuous darkness

Circadian rhythm: daily rhythm with period close to 24 hours (Latin *circa* = about; *dies* = day).

Period: τ (tau): natural period of the circadian rhythm. In practice, time of onset of activity in LL or DD averaged over several days.

Entrainment: When environmental factors modify a circadian rhythm such that it has an exact period of 24 hours as it happens in nature.

Zeitgebers: Environmental cues (LD cycles for example) which entrain biological rhythms.

Free-run: State of the rhythm in LL or DD and constant temperature.

Phase: Any point along the circadian rhythm. Often expressed as CT (circadian time) denoting that it is not local time. (e.g. Sunrise = CT 0 hrs; Sunset = CT 12 hrs).

PRC: Phase response curve. Plot of the responses of a circadian rhythm, in terms of phase shifts, to perturbations (discrete displacements of the rhythm on time of day — X-axis) as a function of phase. (0° phase = CT 0 hrs; 180° phase = CT 12 hrs). Perturbations can be light, temperature, chemicals, social stimuli, etc. In this review, only light pulse PRCs are described.

Housing of Bats and Experimental Methods

Freshly captured bats that had been kept in the laboratory for close to a week, in a normally lit room, were used in the experiments. Our first problem was the capturing of the bats, but we soon became experts at catching them in fine mesh nylon mist nets. *Taphozous* spp. were the most difficult to capture.

Taphozous melanopogon: Body weight 20-24 g, best hearing frequency 26-28 kHz.

Field observations: This is a very common species and hunts high above the canopy in the open air. The field observations were made in the rock complex of the Jain Hills (Samanar Malai) in the vicinity of the Keela Kuyil Kudi village some 8 km southeast of the Madurai Kamaraj University campus. A colony of 150-180 animals of both sexes inhabited the vertical cracks and deep crevices of the rocks facing north. The bats crouched on all fours in clusters of 6-8 in the inner recesses of the crevices, some of them leading to dark, dank caves which progressively became narrow and inaccessible to observers. Older males and females often roosted in regions closer to the entrance, and were visible for observations during the daytime, often bathed in sunlight. Early observations lacked details about cluster size, sex composition, age distribution, hierarchical order, and exact numbers, for we had not yet acquired infrared viewers. Later observations by R. Subbaraj (unpubl.) confirmed the observations of Brosset (1962a) that the species was extremely polymorphic, variable in size and colour. Males were bearded. Later observations were made from comfortable perches, on a colony that lived in the outer yard of a temple 6 km west of the MKU campus on the banks of a bend in the Vaigai river.

Information on the various species of insectivorous bats of the Madurai region, location of cave sites, observing techniques of evening exodus flight of bat colonies, foraging areas and the bat lore could be obtained orally from the villagers living around the MKU campus. Bat counts were made during the onset of colony activity following sunset, the observer lying on a rock surface at the cave mouth and looking upward against the dimly lit dusk sky and counting the swift outward flight of the bats. In later studies, we used an infrared sniper-scope (FJW Industries, USA). Light intensity was measured during evening out-flight at the cave mouth using an AEG luxmeter and an optometer (United Detector Technology, USA). The lowest level of light intensity that could be directly and reliably measured with the luxmeter was 0.25 lux, but using the optometer on the energy scala scale we have measured 5% of starlight intensities (*c.* 0.0001 lux). Counting the bats when they returned to the cave was a more weary exercise, for each bat returned at its own time.

Captive bats were kept in the laboratory in 1 m x 1 m x 1 m wooden frame cages, wrapped around with nylon mosquito net, with a sleeve to put a hand in to feed the animals, change the drinking water, etc. Our German colleagues working in their laboratories, procured meal worm, commercially available in Germany, in abundance to feed their bats. Our meal worm was of very small size, so we resorted to feeding our bats on de-gutted cockroaches with elytra, wings, outer cuticle and legs removed. First the bats refused this unnatural fare but learnt to eat it after a sufficient build-up of hunger. They were always fed at night, and in later experiments during day into activity time, when we had offered the bats inverted light/dark (LD) cycles of 12:12 hours, with dark prevailing from 0800 hrs to 2000 hrs. Water with a few drops of Vitamin B-12 was available *ad libitum*.

Taphozous kachhensis: Body weight 48-54 g, best hearing frequency 24-26 kHz.

This is the largest and most sturdy species among the commonly occurring echolocating bat species in Madurai. It is as fast a flier as *Tadarida*, foraging at high speed (10-15 m/s) at heights of 17-30 m above the ground in unobstructed areas. A colony of these bats lived in the deep cracks and crevices of a rock complex called Pannian Malai, 5 km west of the MKU campus, not far from the road leading to Theni and Thekkady. The eyes of the bats were seen glistening during the day, when one peered into the cracks and crevices. The temperature in the inner recesses of the crevices was interestingly much cooler, at 27 to 28 °C, than outside where the temperatures could rise to 42 °C in the summer months. Both *Taphozous melanopogon* and *T. kachhensis* clung to the rock face on all fours. Unlike *T. melanopogon*, *T. kachhensis* was never seen roosting in temples or other human artifacts.

For experimental recording of the locomotor activity of both *T. melanopogon* and *T. kachhensis*, which did not fly within limited spaces but moved swiftly and laterally on all fours, we devised sturdy wooden tilting cages of 50 cm x 30 cm x 20 cm with a sliding door at one end and mesh net at the other. The cages were poised on knife edges and would tilt laterally, picking up the slightest ambulatory movements of the bats. The tilts activated the writing stylets of 20-channel A 620 X Esterline Angus Event Recorders (Esterline Angus Electronics Co., Indianapolis, USA). Experiments were performed in photographic darkrooms (chronocubicles) in desired DD, LL or LD conditions. Red light >630 nm was used to represent darkness ('safe light'). The temperature in the chronocubicles was constant at 28 ±1 °C and the relative humidity was artificially raised to 60 to 65% for experiments with *Taphozous melanopogon* and *T. kachhensis*.

A small colony of 25 *Taphozous kachhensis* bats comprising both sexes was maintained in an outdoor bat enclosure of 7.5 m x 3.0 m x 3.75 m with a fishpond of dimensions 4.15 m x 2.39 m x 0.64 m filled with water. Frogs in good numbers were introduced into this pond. The water in the fishpond helped to increase the relative humidity inside the enclosure. The sides of the enclosure were limited on all four sides, by walls 2 m high and the enclosure was roofed over by steel rods forming a grating, which permitted the air movement but was too restrictive for the bats to fly or squeeze out. The enclosure was in the midst of a mango grove in the Botanical Garden. A row of *Polyalthia longifolia* trees on the east side of the enclosure, and mango trees on all sides, provided shade in the early morning hours. At the east end of the pond was a dark wooden enclosure in which bats roosted during daytime. The humidity varied from 35 to 65% and the temperature from 22 to 30 °C. This outdoor bat enclosure was our own idea and the outfit came in handy for the 'Prey capture by the false Indian vampire bat' experiments (Habersetzer and Marimuthu 1986, Marimuthu and Neuweiler 1987) and for video recording flight patterns of our bats. The onset of flight activity following the sunset and end of activity of the group of captive *T. kachhensis* bats were monitored for a whole year from January 1979 to January 1980. These bats flew around and fed on insects attracted to a mercury lamp (125 W) mounted within the enclosure. The bats drank the water from the pond.

Hipposideros speoris: Body weight 6.5-7.0 g, best hearing frequency 137 kHz.

This bat typically forages close to the canopy, around bushes and trees and very close to obstacles. A colony of 550-600 bats inhabited a true cave, which was 40-45 m deep in some of its pockets, in the Jain Hills. Actual observations of emergence flight of bats and their return were made at this site (Marimuthu 1984). In a nearby cave, which was more a hollow in a rock-front, lived a much smaller colony of *c.* 50 bats of *Hipposideros bicolor fulvus.* The mortality after capture of these bats was so high that it was decided that G. Marimuthu and Dilip Joshi would work with the sturdier *H. speoris.* As a result, we have accumulated a wealth of information about the biology, behaviour and circadian rhythms in this species. These bats also lived for long periods of time in captivity in good health.

Freshly caught bats were brought to the laboratory and placed in a 1 m x 1 m x 1 m nylon mosquito mesh cage for a week to allow them to acclimatise to the laboratory conditions. These bats spaced themselves out without ever clustering. In fact, each male bat had his 'personal' space, inside the cave as well as in the laboratory, which he would defend from intruders. The average space between two neighbouring male bats was 18 ±3 cm (n=12 observations on 46 animals) (Selvanayagam and Marimuthu 1984). Females seem to choose their roosting position in relation to males. Males, in addition to urine-marking their personal space, also adhere to a strict hierarchy in their roosting (Chandrashekaran, unpubl.).

For the experiments, the bats were brought into the chronocubicles and housed in flight activity cages of dimensions 30 x 30 x 30 cm, one bat in one cage. The cages had light aluminium frames and were covered with mosquito mesh netting and suspended from firm arms of tripod stands with strips of spring. *H. speoris* bats resorted to brief bursts of sustained flight and such activity jiggled the cages. The vertical oscillations and displacement of the cages depressed microswitches activating the stylets of Esterline Angus Event Recorders.

In the cave experiments performed by my students, G. Marimuthu (from 1978 to 1983) and Dilip Joshi (from 1980 to 1985) the same actograph (activity recording device), as described above, was used, employing a hand-wound Lambrecht-KG-Göttingen thermohygrograph instead of the electricity-run Esterline Angus Event Recorders. The thermohygrograph completing one revolution in 24 hours was adopted for tracing activity/rest patterns by writing ink stylets fixed on the flank of activity cages. The sturdy set-up, shown in Plate 1, Fig. 1, was placed 40 m deep into the cave. The activity/rest patterns of three bats

Chandrashekaran, M.K.: Thermohygrographs

PLATE 1

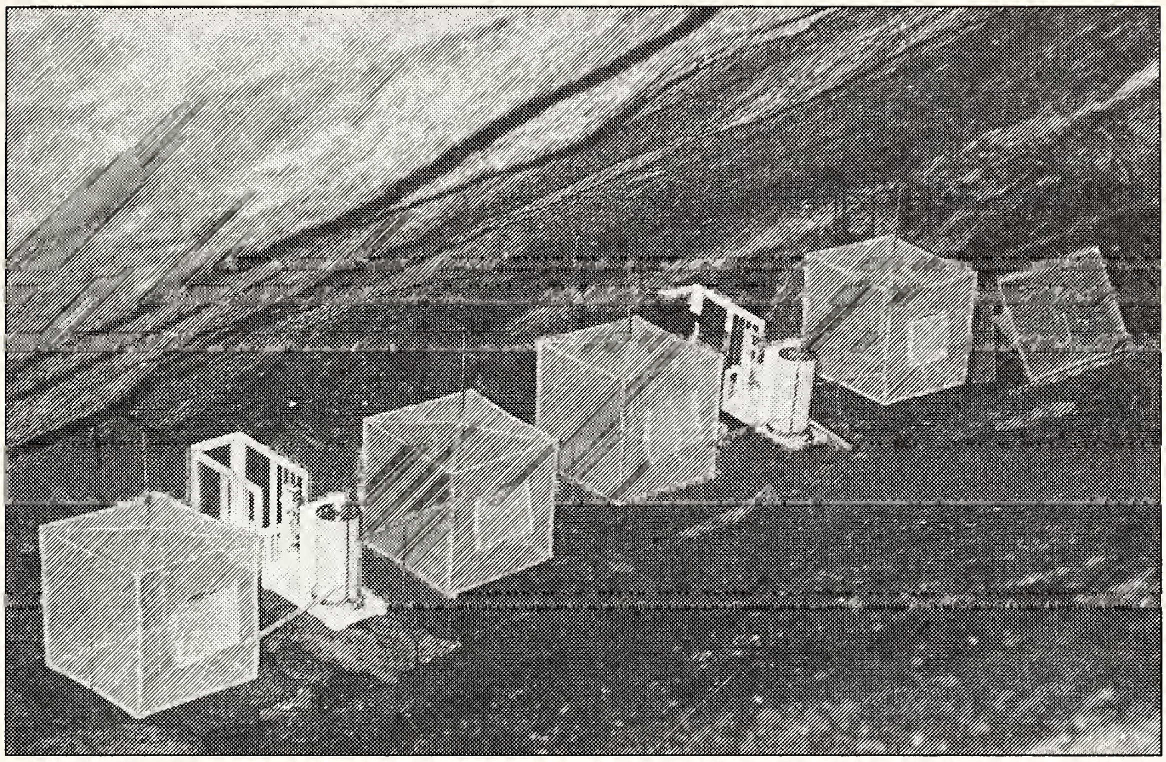


Fig. 1: The experimental set-up of suspended flight activity cages and hand-wound thermohygrographs

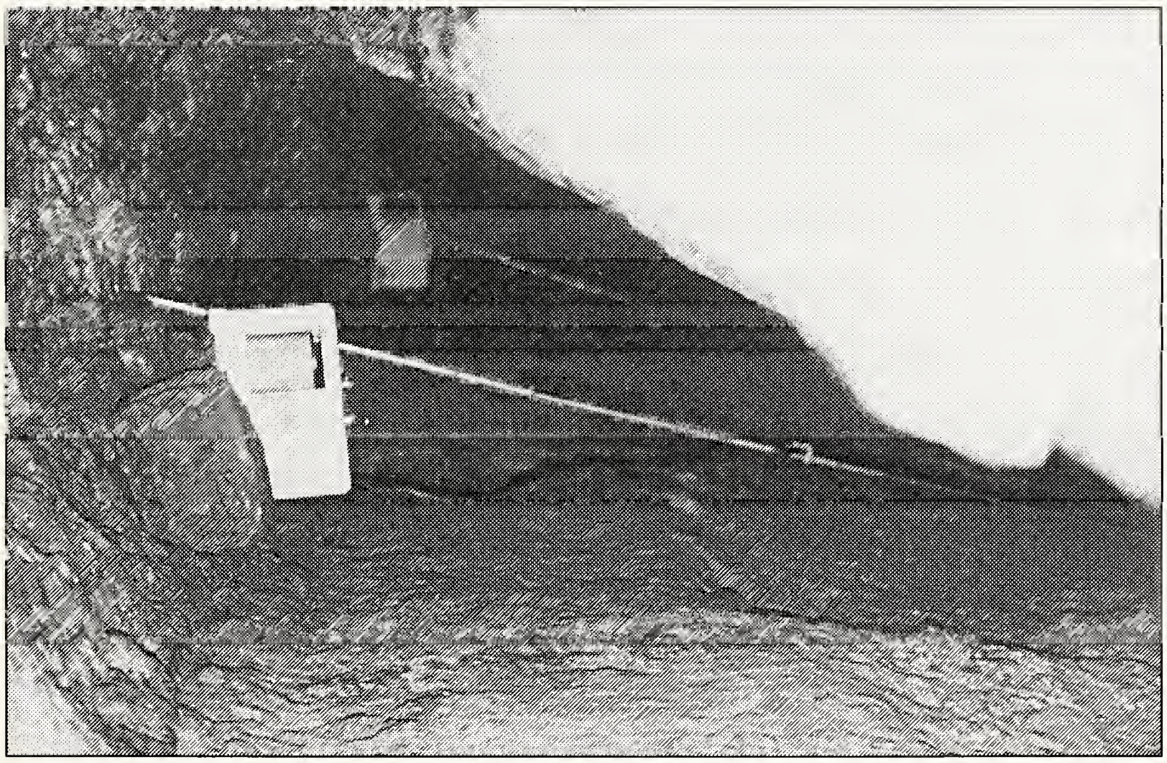


Fig. 2: Thermohygrographs placed in different parts of the *Rhinopoma hardwickei* cave

could be simultaneously traced, the longest experiment lasting up to 60 days. The ambient temperature in the chronocubicles was 28 ±1 °C and relative humidity was maintained high at 85 ±5% (since the relative humidity in their cave is 90% or higher).

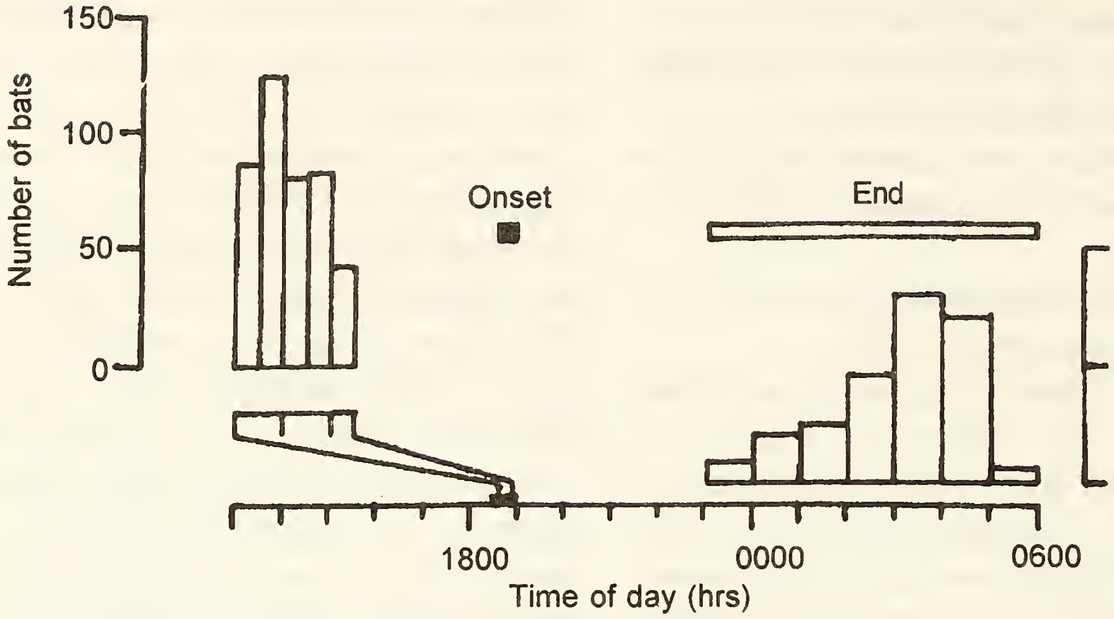
Rhinopoma hardwickei: Body weight 14-15 g, best hearing frequency 35 kHz.

Rhinopoma hunts flying insects at medium heights of up to 10 m above the ground and always keeps away from dense background. A stable colony of *c.* 1,500 bats of both sexes of the mouse tailed bat *Rhinopoma hardwickei* roosted in a narrow cave with high ceiling in the western flank of the Nagamalai Ridge, which forms the backdrop to the MKU campus. The population was intensively studied (Usman *et al.* 1990) for emergence and return flight patterns from August 1978 to August 1979. Additional observations were made during the period January to December 1980. The temperature and relative humidity in the various pockets of this irregular cave were measured using thermohygrographs. Wind conditions were recorded with a portable wind meter (Lambrecht KG Woelfle type) erected on a tripod stand in the study area. Sunrise and sunset times for all our field experiments were obtained from the Indian Ephemeris Nautical Almanac published by the Director of Observatories, Kolkata and were adjusted for latitude, longitude and Indian Standard Time. No laboratory experiments were performed either with *Taphozous kachhensis* or *Rhinopoma hardwickei*.

RESULTS OF FIELD ETHOLOGY AND LABORATORY STUDIES

Activity and roosting patterns of a colony of *Taphozous melanopogon*: Voute *et al.* (1974) and DeCoursey and DeCoursey (1964) had observed that members of their bat colonies of *Myotis* spp. crowded at the entrance to their roost before flying out in the evenings to forage. In Germany, Rudolf Rübsamen and Michael Eckrich, who had each spent a few weeks and a whole year respectively at MKU, took me to the countryside churches in Upper Bavaria to see huge colonies of *Myotis `myotis* roosting there. At sunset, these bats came to ledges from where they appeared to be 'sampling light' for close to 40 minutes in the long twilight of the higher latitude, before taking off. Such 'light sampling' behaviour could not be established for *T. melanopogon*. On the other hand, these bats appear to be exposed to the ambient light all through the day and could perceive nightfall, which came in a matter of 6 to 8 minutes in Madurai, directly. The time of the first flier could be generalised as the exact time of onset of foraging flight activity of the colony, for hordes of bats followed within seconds in clusters of 6 to 8. These observations were made at intervals of 10 days during January 1975 to January 1976. The difference between the longest and shortest days in Madurai is well below 2 hours. The entire colony empties out within 18 to 21 minutes, indicating great inter-individual synchrony in onset of activity but *not* in its termination, as shown in Fig. 1. Even though the time of sunset during the course of the year varied over a range of 41 minutes, the bats showed astonishing rigidity in the time of their emergence which was restricted to a narrow 'gate' of 16 mins, where the first bat emerged between 1825 hrs and 1841 hrs. The onset of foraging flight of the first 'sentinel' bat under field conditions, plotted against the months of the year, is illustrated in Fig. 2. Each dot of the 2 sets of 36 dots represents single observations on the 'onset' and 'end' of the activity of the bat colony made at 10-day intervals from January 1975 to January 1976.

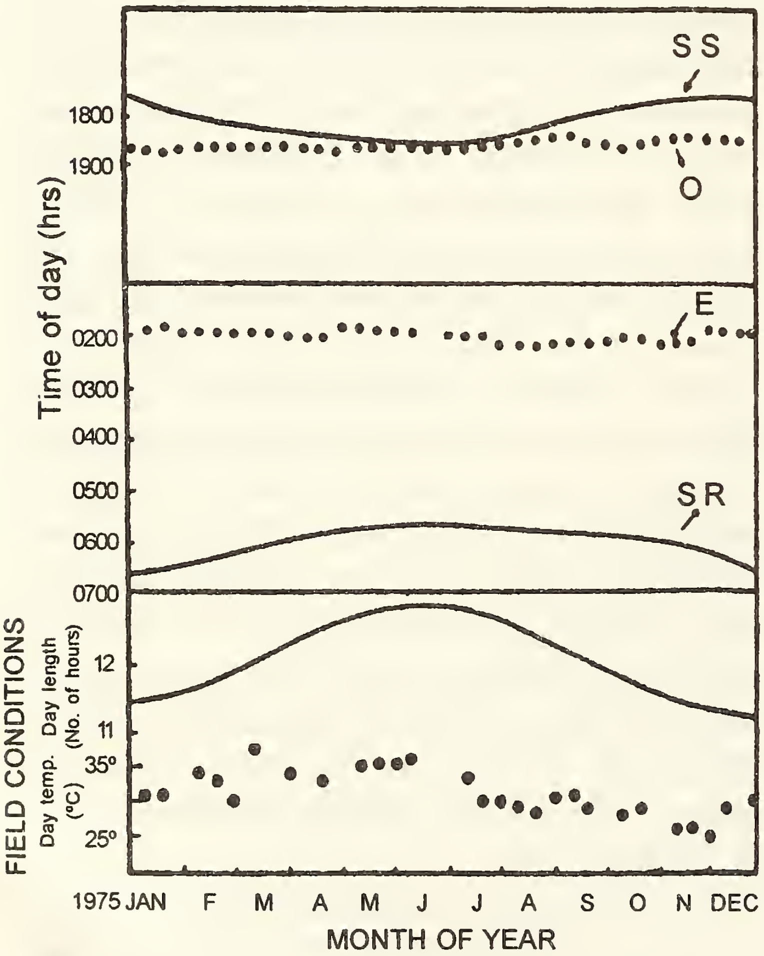
The precise timing of emergence of the bats is well illustrated by the following incident. Eberhard Gwinner (Director MPI for Behavioural Physiology, Andechs, Germany) was visiting me in 1977 and wanted to see for himself this great precision in the onset of the outward foraging



■ = Time taken for first bat to last bat to emerge (mere 22 minutes)

▭ = Time taken for return flight (spread over 6 hours and 14 minutes).

Fig. 1: Pattern of 'onset' and 'end' of the nightly foraging flight of members of a colony of *Taphozous melanopogon* (After Chandrashekaran *et al.* 1983). Actual numbers flying out and returning do not tally since the bats took different routes, especially during the onset of foraging flight.



O = Onset of activity, E = End of activity.
SS = time of sunset, SR = time of sunrise.

Fig. 2: Field data of flight activity of *Taphozous melanopogon* bats (After Subbaraj and Chandrashekaran 1977)

activity of the colony. We took him to the site. Gwinner lay on a rock facing the crevices and was impatiently looking at his watch and called out at 1826 hrs, "Where are your bats?". The exodus started within seconds of the question and Gwinner was greatly impressed.

The timing of end of activity was imprecise in all seasons. The narrow gate in the timing of emergence flight implies that there is a seasonally changing threshold in sensitivity to twilight. Thus bats began flying when it was very dark on short days (0.1 lux) and flew out in sunlight even as the sun was going below the horizon (50 lux) on long days. It is unusual for a nocturnal mammal not to have a reasonably definable and fixed lower light intensity as a trigger to nightly activity, and therefore our findings need to be further investigated. Our findings are also at variance with the observation of Brosset (1962a) on *Taphozous melanopogon*, "The nocturnal outings of the colony take place 25 to 30 minutes after sunset (Kanheri and Mandu)". But Brosset, of course, as he himself has pointed out, did not make a systematic year-round study of these phenomena.

Werner Siefer, a project student of G. Neuweiler, who was visiting us in 1990, declared one day that he had seen bats 'soaring' at heights of *c.* 200 m soon after sunset. My response was that it was not possible for bats to soar. Textbooks tell us that bat wings are designed for flapping flight. "To stay airborne, a bat requires 8-15 wingbeats" (Neuweiler 2000). R. Subbaraj was requested to look into the matter. He accompanied Siefer with a pair of powerful binoculars. It was a warm full moon evening and it had drizzled. The bats were indeed soaring 150-200 m above the Jain Hills rock formation (Siefer and Kriner 1991). R. Subbaraj identified the species as being probably *Taphozous kachhensis*. The bats were apparently soaring in the thermal layer arising from the rocks below and cropping a rich fare of insects. Unfortunately, this interesting phenomenon was not further investigated, since both Werner Siefer and Eva Kriner left for Munich soon after making the discovery. It makes sense to assume that these bats had switched off their echolocation system while soaring, and the insects would have been plentiful anyway. They just had to soar with their mouth open and close it with a mouthful of insects.

Activity and roosting patterns of a colony of *Hipposideros speoris*: The observations on onset and end of activity were made at fortnightly intervals from December 1977 to January 1979. It was possible to count bats flying out in the twilight, against the still blue sky. The time of emergence of the first bat was recorded, and thereafter the number of bats emerging every minute was counted for as long as the prevailing twilight permitted. Light intensity was measured during the evening out-flight at the cave mouth, using the optometer with the photosensor pointing to the zenith.

Prior to emergence, approximately an hour before sunset, bats become restless and exhibit circular scanning head and ear movements, wing flapping, elaborate autogrooming, rocking forward and backward, and brief stretches of flights. The ear and head movement, noticed through the noctovision apparatus, may just mean that these bats were echolocating our presence in the total darkness of their roosting site. The commotion inside the cave gradually builds up, but since adults of *H. speoris* are "silent" and only produce ultrasonic pulses of 134 kHz, in this case there is none of the noisiness associated with the onset of colony activity in bats of other species. Flying around of the bats also intensifies the smell of bat guano inside the cave. When the light intensity steeply decreases during sunset, bats fly farther and farther toward the entrance of the cave. Bats of both sexes live in the innermost recesses of the cave. The darkness in the deeper parts is absolute and 1000 seconds exposure of the photoelement of the optometer on the energy scala scale did not register any light. About 10 to 20 minutes after sunset, in all seasons, a solitary bat invariably darts out of the cave to return immediately. We have never been able to verify if it was the same 'alpha' bat that emerged every evening and banding the bat did not help. A little before exodus, the entire colony of bats remain milling around very close to the cave mouth 'sampling light' (Twente 1955), then groups of 10 to 15 bats break off and fly into the night sky. However, on any given night, about 3 to 5% of the bats remained inside the cave. It was not possible to determine the returning time with any degree of accuracy, since bats flew in and out throughout the night. Further, bat mothers returned frequently to check if their pups were safe, when they did not carry them to the foraging sites. Evening departure of bats usually occurred at low twilight intensities that ranged over the seasons from 4.5 to 40 lux. Fig. 3 summarises the findings on *H. speoris* (Marimuthu 1984). It is clear from the figure that the onset and end of colony activity systematically changed and remained close to the timings of sunset and sunrise, respectively.

Fig. 4 illustrates the pattern of emergence flight of the colony of *H. speoris* made on four nights, in December 1977 (short daylength), March (neutral daylength), June (long daylength) and

October 1978. The bat counts were made every minute and shown here added up for five minutes. The pattern of scattered emergence on the night of June 23, 1978 might have resulted from the frequent outward and inward flight of suckling bat mothers. Fig. 5 is a representative example of end of activity of the colony where numbers build up with approaching sunrise and terminate abruptly. The precision in the timing of onset and end of activity over various seasons in the colonies of insectivorous bats has been reported by many authors (DeCoursey and DeCoursey 1964, Erkert 1976, 1978, Griffin and Welsh 1937). The actual onset of exodus in *Hipposideros speoris* is preceded by arousal, which is obviously accomplished by the endogenous circadian rhythm acting like a wake-up timer. The light sampling is actually employed to fine-tune the circadian clock. A bat that tries to fly out before its time is exposed to bright light, which causes the clock to delay its functioning. Similarly, a bat that does not return to its cave early enough would be exposed to the bright light of the rising sun. A light pulse shock, at that phase in the animal's clock, 'advances' the phase. These discrete phase delays effected by light during sunset, and discrete phase advances effected by sunrise, explain how the bats do not fly about at unusual hours in nature. This tuning of the biological clocks by light is called entrainment (Aschoff 1960, Pittendrigh 1960).

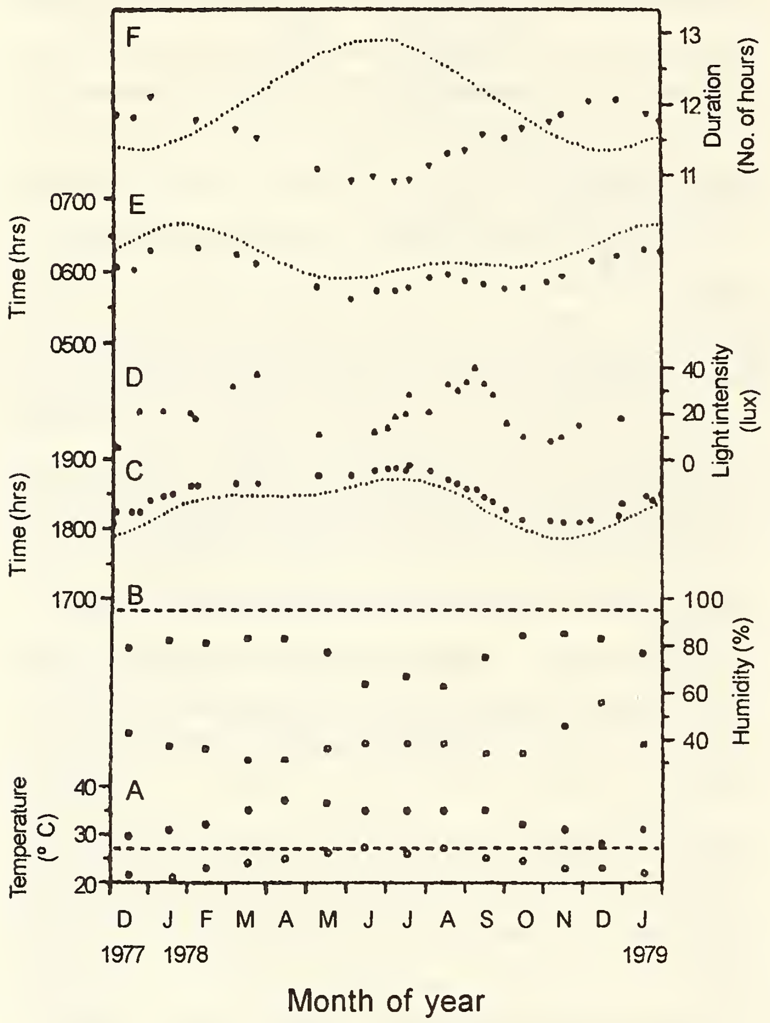


Fig. 3: Summary of the nocturnal activity pattern of a colony of *Hipposideros speoris* for the period of a year (After Marimuthu 1984)

Key to panels:
A: Temperature variations at time of onset of activity. Upper (solid) circles = temperature maxima, lower (open) circles = temperature minima, broken straight line = remarkably constant temperature of 27 °C inside the cave.
B: Maxima and minima of humidity.
C: Sunset (dotted line) and onset of colony foraging flight (solid circles).
D: Light intensity.
E: Sunrise (dotted line) and end of colony activity (solid circles).
F: Relationship between daylength (dotted line) and duration of activity (solid circles).

Activity time: Marimuthu (1984) has made a fine structure analysis of the seasonal changes in the precision of the onset and end of the *H. speoris* colony activity under natural photoperiodic conditions. The duration of activity of the colony was measured as the time elapsed between the flying out of the first bat and the return of the last bat. The duration of activity followed the seasonal changes in the photoperiod, being longer over shorter daylengths and shorter over longer daylengths, indicating a positive correlation between the duration of colony activity and the length of night (Fig. 6). Fig. 7 represents the regression analyses of the timings of sunset and emergence of the first bat, and Fig. 8 represents the regression analyses of the timings of sunrise and return of the last bat, over the seasons. The lower light intensities triggering the onset of colony activity

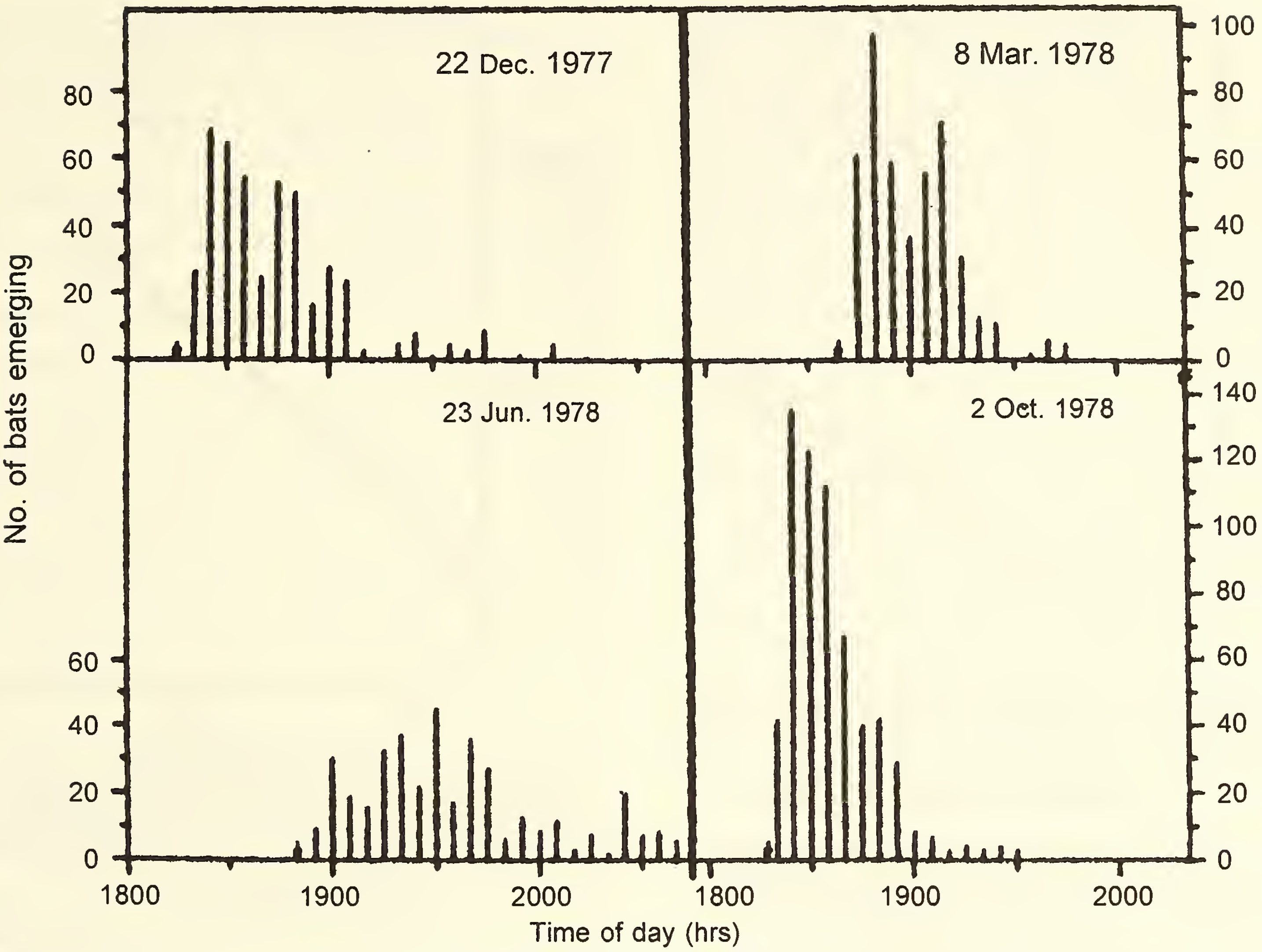


Fig. 4: Representative examples of the pattern of emergence of members of the colony of *Hipposideros speoris* (After Marimuthu 1984)

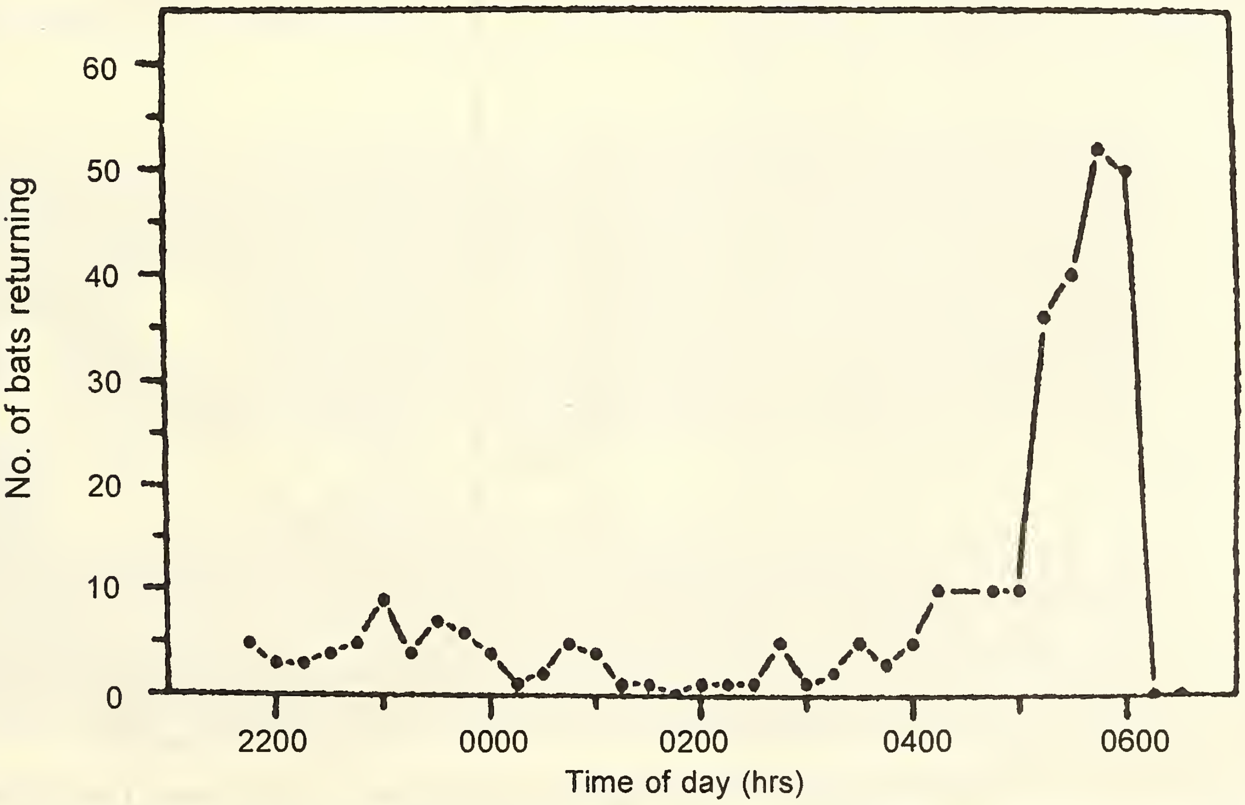


Fig. 5: Representative pattern of return of members of the *Hipposideros speoris* colony over the course of an entire night (After Marimuthu 1984)

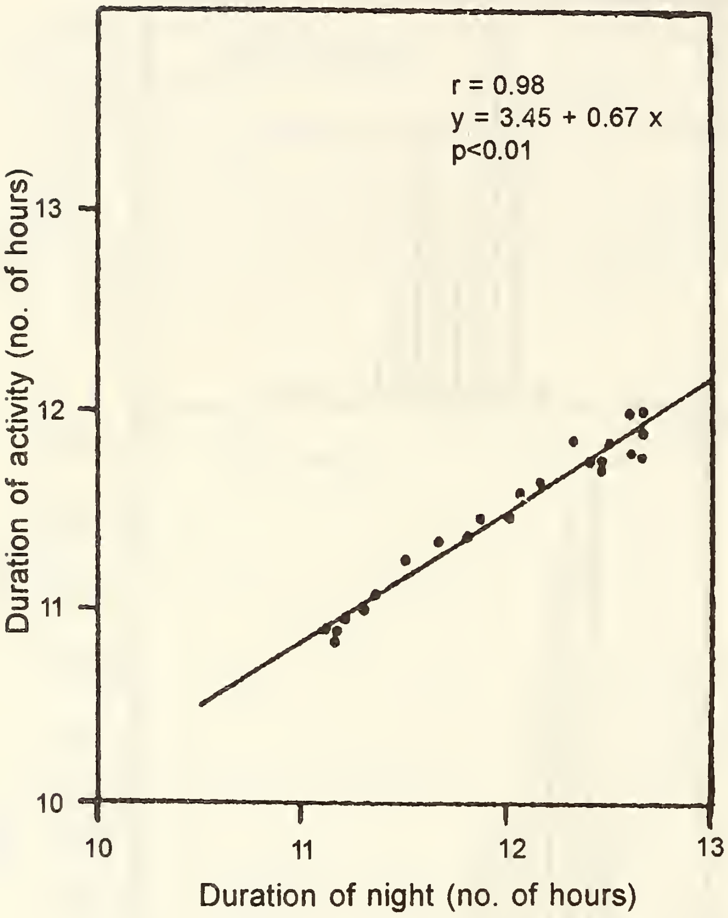


Fig. 6: Correlation between activity period of *Hipposideros speoris* and duration of night (After Marimuthu 1984)

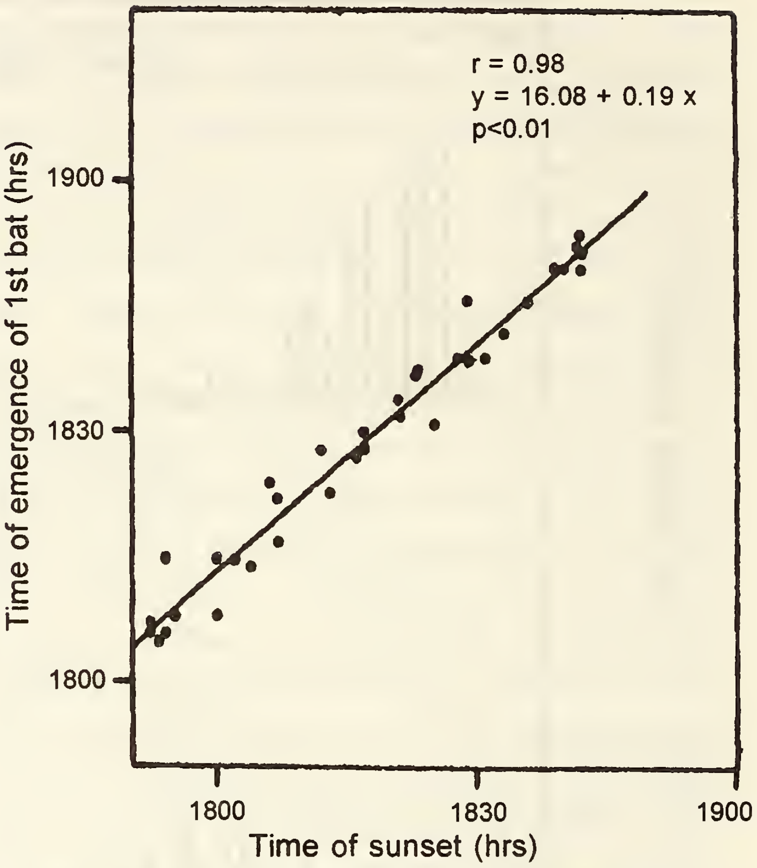


Fig. 7: Linear regression of time of emergence of the first *H. speoris* bat of the colony in relation to the time of sunset over the seasons (After Marimuthu 1984)

varied marginally over the seasons, indicating that there is no fixed lower threshold. The rate of change of light intensities during the brief dusk and dawn appears to be the primary and reliable environmental cue for these bats to modulate the onset and end of activity. It was not possible to precisely determine the beginning of return flight, because the bats indulged in both inward and outward flights sporadically during most of the night. By around 0300 hrs, the flight was essentially back to the cave and the build up in numbers was impressive an hour before sunrise. At this time the bats did not dash into the cave but undertook circling flights near the mouth of the cave at an altitude of one or two metres. The precise function of these manoeuvres is not clear, but it has been understood by us that the bat was daily fortifying its place memory. The bats then ceased to emit the trains of ultrasonic pulses and literally dived into the cave. These findings on activity duration, onset and end, relative to the

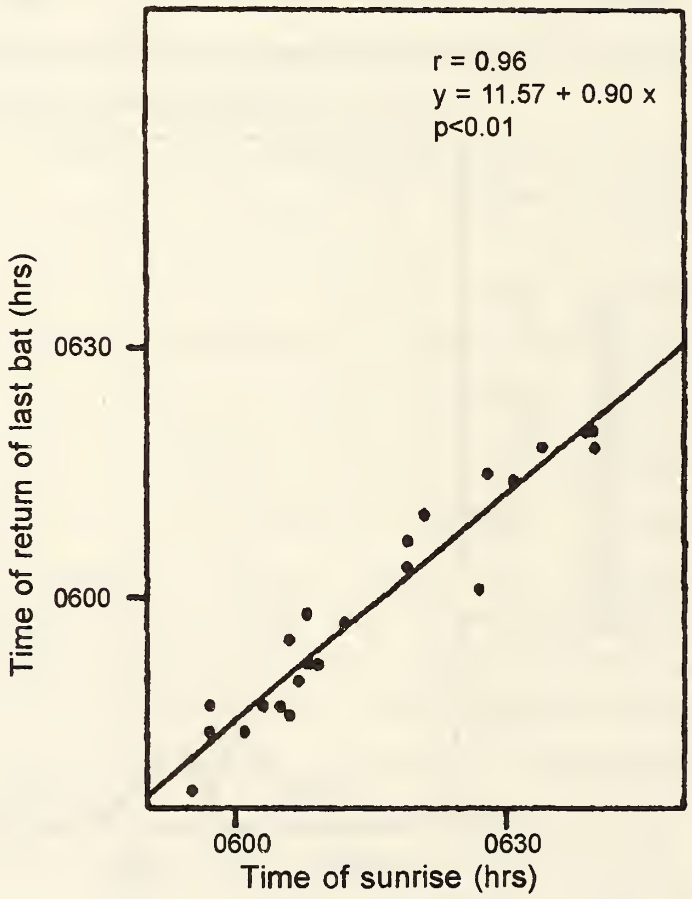
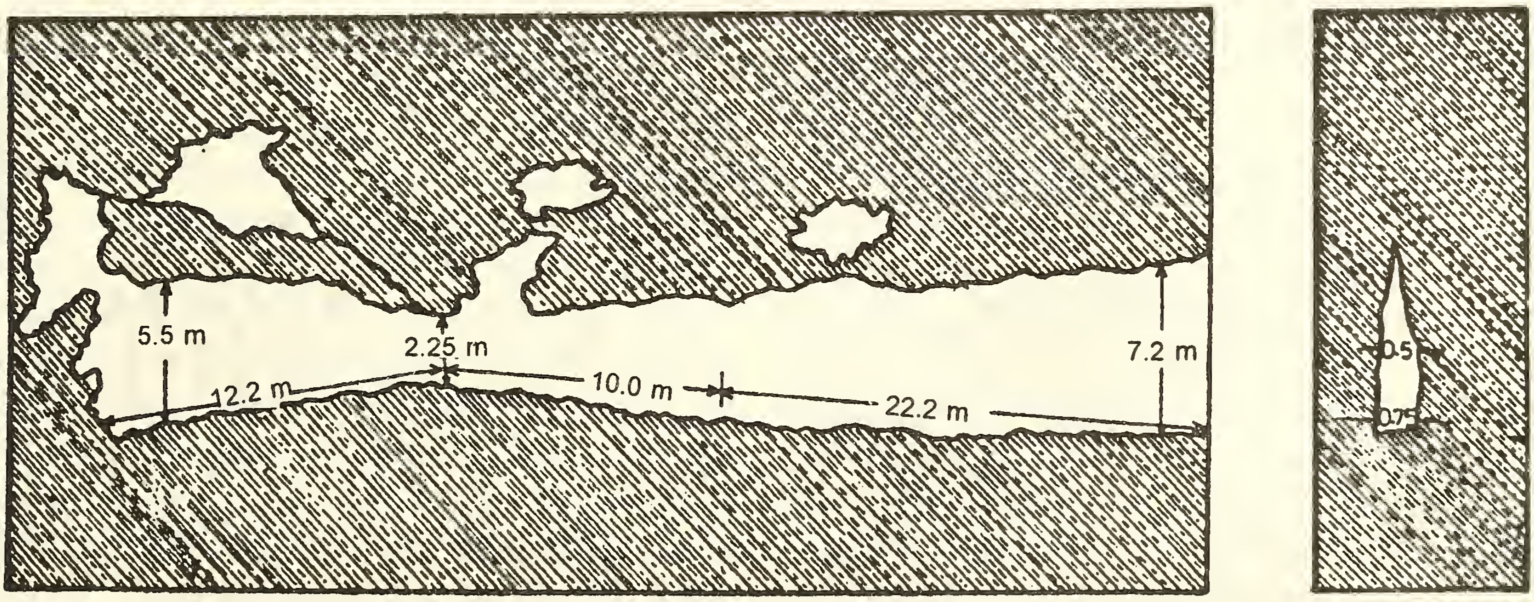


Fig. 8: Linear regression of the time of return of the last *H. speoris* bat of the colony in relation to the time of sunrise over the seasons (After Marimuthu 1984)

daylength (photoperiod) are in accordance with the rules formulated by Aschoff (1960, 1969) for diurnal and nocturnal animals, known as Aschoff's Rule (Pittendrigh 1960). Marimuthu's (1988) studies of these parameters in *H. speoris* were the first of their kind on a tropical bat species.

Activity and roosting patterns of a colony of *Rhinopoma hardwickei*: A number of caves, caverns and crevices that accommodate bat colonies exist in the Nagamalai Ridge. There, we decided to study a colony of *Rhinopoma hardwickei* which in many ways was different from *Hipposideros speoris.* The first feature I noticed was that there was an unmistakable smell, and that the members of the colony were found in all parts of the cave and roosted in different parts of the cave at different hours of the day. There certainly was nothing like 'personal space' or a marked hierarchy. These bats have two kinds of roosting positions, either resting on all fours like *Taphozous* spp. or hanging free like *Hipposideros* spp. The cave was more like a crevice and its topology is shown in Fig. 9. During field observations I noticed that most bats of the colony were close to the spacious high-roofed (*c.* 7.2 m) cave mouth which faced the west, in the cooler hours of the morning. The bats frenetically waved their prehensile and longish tails by means of which they detected and crept into narrow cracks in the wall of the cave. Plate 1, Fig. 2 shows the thermohygrographs placed at different positions inside this cave. With the help of special, elongated thermal probes, we could measure the temperatures prevailing in nooks and corners. The bats roosted in big clusters of 30-40 animals and the clusters moved progressively inwards in the cave, which was very dark and very cramped — in places, less than 1 metre wide — for the observer to position himself. By evening they had all crouched in inaccessible recesses and cracks in the inner walls of the cave. Careful measurement of the ambient temperature at the sites in which they roosted indicated that the bats were moving to zones of constant temperature of 27-29 °C. A rough sketch about how a cluster of bats moved on a hot May day is shown in Fig. 10. In *R. hardwickei*, constancy of temperature of *c.* 27 °C was possibly being sought by the bats rather than absence of light. This might also be the situation with *Taphozous melanopogon* and *T. kachhensis,* with none of the three species having well-marked 'personal space'.



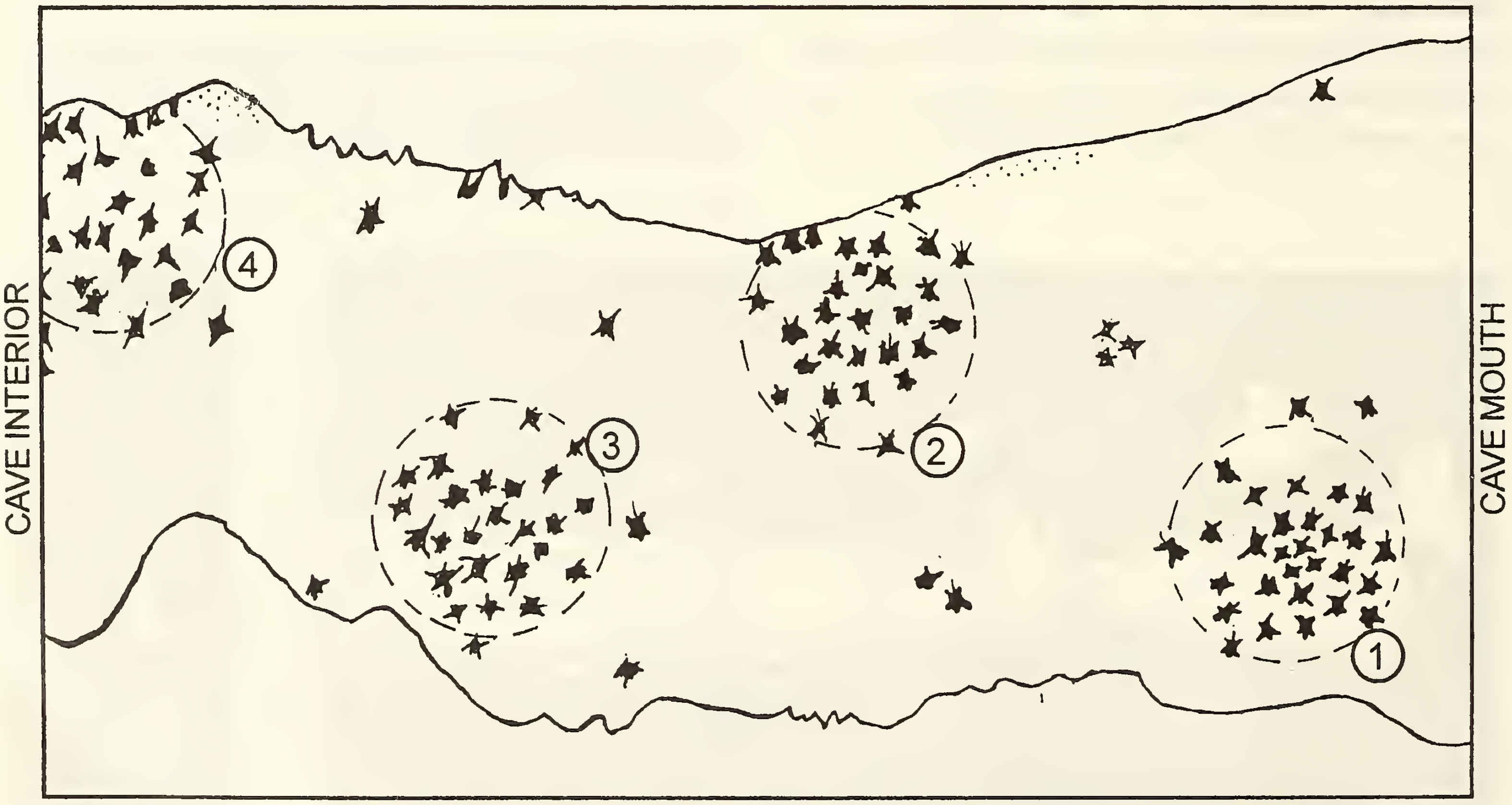
LONGITUDINAL VIEW

FRONT VIEW

Fig. 9: Topology and dimensions of the cave inhabited by the colony of *Rhinopoma hardwickei*

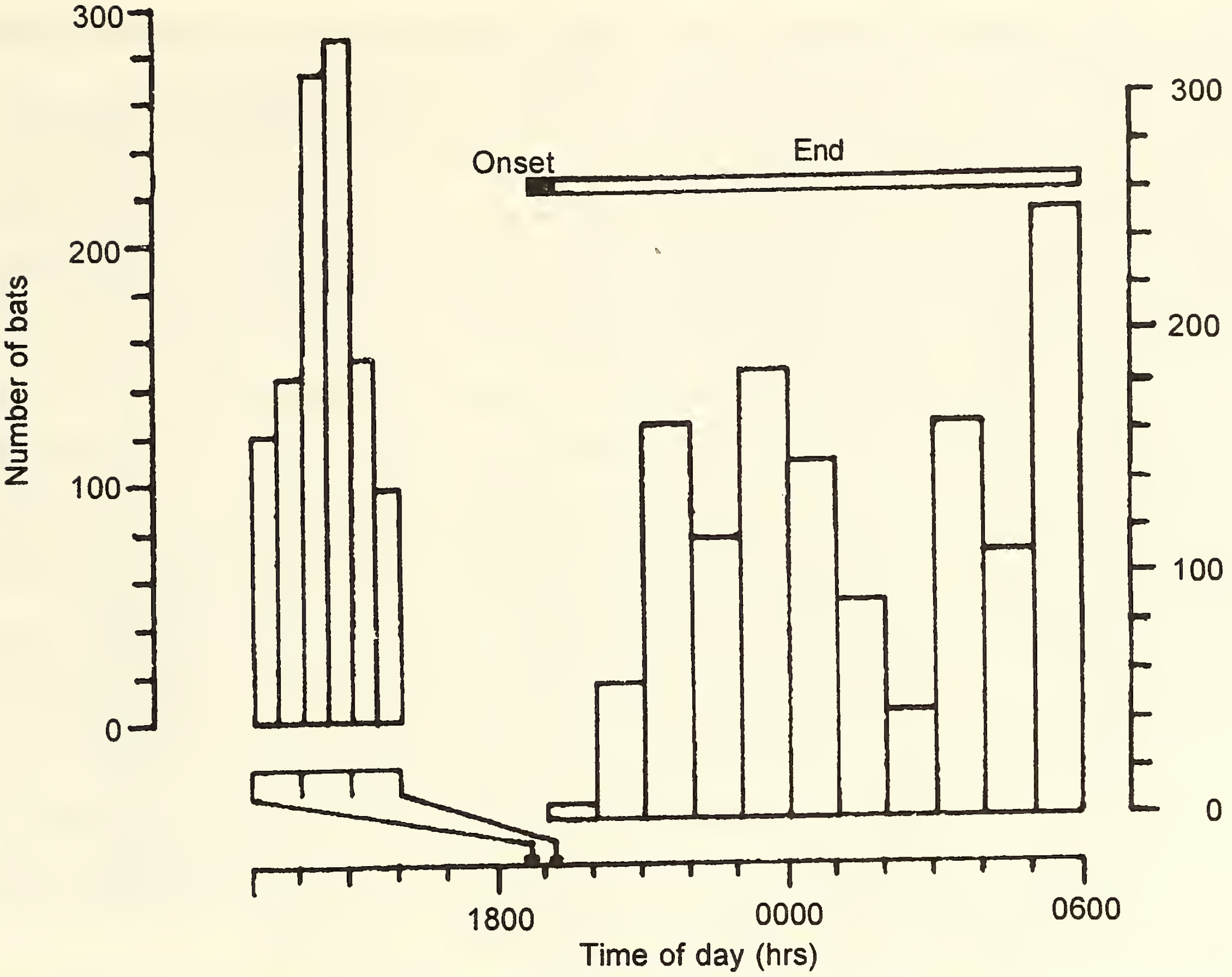
The *Rhinopoma* colony was also the biggest in terms of numbers. Prior to exodus flight, the members of the colony indulged in intense audible and shrill vocalisation which was literally amplified at the cave mouth. Fig. 11 summarises patterns of onset of colony activity accompanying sunset and return of the bats after foraging (Usman *et al.* 1990). The exodus flight is impressive, like a cloudburst, with the members scattering to fly to their foraging sites. Emergence of the colony kept pace with the seasonally varying time of sunset and the ambient light at the cave mouth, which varied between 1.0 lux during shorter days to 60 lux during the longer days of summer.

One striking feature, which is common to the nightly emergence of the colonies of *T. melanopogon, H. speoris* and *R. hardwickei,* is that the members of the colonies pour out synchronously. However, the return flight is spread over the night and not predictable. Based on such observations, we postulated (Chandrashekaran *et al.* 1983) that the arousal and onset of activity in these animals might be under the control of the circadian clock, whereas the end of activity may be determined by external environmental factors such as wind direction and speed, heavy precipitation and satiation. The most spectacular 'emergence by coup' of bats I had witnessed was on January 12, 2002, in Thailand. I was driven from Bangkok, to a place called Phu Phaman in Khon Kean province, some 450 km northeast, to watch a colony of bats emerge for their evening foraging. My informants themselves had not seen the phenomenon and therefore could not prepare me for the sight awaiting us. We arrived at the impressive cave site situated in a massive rocky hill with a yawning mouth *c.* 50 m high and 30 m across. There were eight tourist buses and hundreds of tourists who were all gazing at the cave. At 1745 hrs, the crowd gasped and we saw a thick black cloud ooze out of the cave and stream along the left flank of the rock at a height of 150 to 170 m. The bottom ledge of the cave mouth was at an elevation of *c.* 80 to 100 m.



Encircled numbers indicate positions of roosting at given time: 1. 0600-0900 hrs, 2. 0900-1200 hrs, 3. 1200-1500 hrs, 4. 1500-1800 hrs

Fig. 10: Rough illustration of daytime movements of a cluster of *Rhinopoma* bats



Outward flight of colony lasted only 26 minutes (1846 to 1912 hrs) on the evening of counting but return lasted virtually the rest of the night.

Fig. 11: Pattern of 'onset' and 'end' of the nightly foraging activity of the colony of *R. hardwickei* (After Chandrashekaran *et al.* 1983)

They looked, at that distance, like a swarm of bees, but too numerous to count or even guess the numbers. The sun had not set and several kites were gliding aloft. The outflow of thousands upon thousands of the bats continued steadily and lasted seventeen minutes when I saw the last of the millions of bats fly out at a great height, but this time headed in our direction. We were fortunate that a juvenile bat, possibly on his first evening out, fell to the ground close to me. I picked it up, examined it and placed it on a nearby rock. Given its resemblance to *Tadarida aegyptiaca* in Madurai, I presumed that the Thailand bat was *Tadarida brasiliensis*. The fur was dark grey, the bat was wrinkle-lipped, and had a snout like a mastiff. If the species was indeed *Tadarida brasiliensis*, then they were all flying out at great speed of 27 m/s, the fastest bat flight known (Neuweiler 2000). The temperature was 26 °C and darkness descended very soon. Dr. Manjunatha Rao, who took me to the Phu Phaman caves, writes that there are several other caves nearby. I was thrilled to see lovely, stylised statues in bronze, of the locally available bat species, inscribed with the Latin names.

Social synchronisation of circadian rhythms in *Hipposideros speoris*: An interesting feature that we noticed in the exodus flight of the *H. speoris* colony was that bats inhabiting the innermost recesses of the cave, mostly females and subadult males, were the earliest to fly out. A group of Dutch scientists (Voute *et al.* 1974) had noticed a similar phenomenon in the evening exodus flight of a colony of *Myotis dasyncheme.* A major question was: how do bats inhabiting the depths of our natural cave of perpetual darkness, invariant temperature and relative humidity — an environment virtually devoid of time cues — know the time of sunset in Madurai?

We made the first observations inside the cave (Marimuthu *et al.* 1978) with the help of infrared noctovision binoculars. The individuals of the colony were spaced out and hanging by their hind feet from the ceiling. If we approached them, they turned their heads in all directions with quivering ears and flew away if we went too close. But when Marimuthu and I sat still in the afternoon hours, the bats became still and the colony appeared to be in a state of deep rest (sleep?) until *c.* 1700 hrs. Soon after, the bats appeared to show signs of arousal and individual bats stretched their wings, began preening themselves, yawned and began flying about, one by one. Deep in this cave, where we made our observations, the gurgle of an unseen stream of water could be heard. Happenings subsequent to 'arousal' of the colony, such as bats flying to the light sampling chamber, and eventual exodus flight of the members of the colony soon after sunset have been described under 'Activity/roosting patterns of a colony of *Hipposideros speoris.*'

The next question to be tackled was whether each bat had to 'see' for itself the darkening sky outside. If some bats did not come to the cave mouth to sample light, would they still know that the sun has set? Do the volunteer bats relay the information to bats deep inside the cave? We performed the first experiment in which we kept three male bats captive at a depth of *c.* 40 m in flight activity cages (described earlier) for an extended period of 50 days and the bouts of their flight and rest were continuously recorded on the charts of hand-wound thermohygrograph drums described earlier. It soon became apparent that the captive bats began their flight activity at the precise time at which the free-flying conspecifics began their evening exodus flight. The actogram describing the flight activity/rest patterns of the three captive male bats for 40 days in one case, and 50 days in the other two cases, is presented in Fig. 12 (Marimuthu *et al.* 1981). The 24-hour activity/rest strips were pasted on bristol board one below the other chronologically. Activity bouts are indicated by the vertical patches and the horizontal traces indicate rest.

The captive bats were less active when the cave emptied out, but they responded to stray returning bats and to the flock of bats returning in the small hours of the morning. Our excitement was great, for we had confirmed that the free flying bats were telling captive bats the time. Our first communication (Marimuthu *et al.* 1978) was a very short one of less than 400 words based on activity/rest patterns of one captive bat recorded for a mere eleven days inside the cave. Confirmatory evidence of social synchronisation (that is the scientific term) of the circadian rhythms in *H. speoris* came with a later paper (Marimuthu *et al.* 1981). We had also stated that it was not clear to us how the phenomenon took place and suggested involvement of: 1) pheromones, 2) wing flapping noise generated when conspecifics flew out, and 3) acoustic transmission of message.

Even though we were reasonably sure that there was social information of sunset and time of day, we wanted to demonstrate the opposite situation also, i.e. a solitary bat in a solitary cave without 'social informers' cannot synchronise its circadian rhythm to the 24-hour periodicity of bat colony activity. A practical problem was finding a cave good enough to be habitable for bats but still not colonised. When, finally, we did find a solitary cave without hipposiderid bats, we performed an experiment by placing a solitary male *H. speoris* in a flight activity cage and recorded its flight activity/rest patterns inside the cave. The solitary bat was indeed helpless in the strict 24-hour periodicity of the onset and end of its activity, as is shown in Fig. 13. The circadian activity rhythm in the flight activity free-ran with a period < 24 hours in the continuous darkness of the cave (Marimuthu *et al.* 1981). The bat began its nightly flight *c.* 20 mins earlier each *subjective* evening. We terminated our experiment with a touch of bravura. After 50 days in captivity and free-run of its circadian rhythm, our bat began its

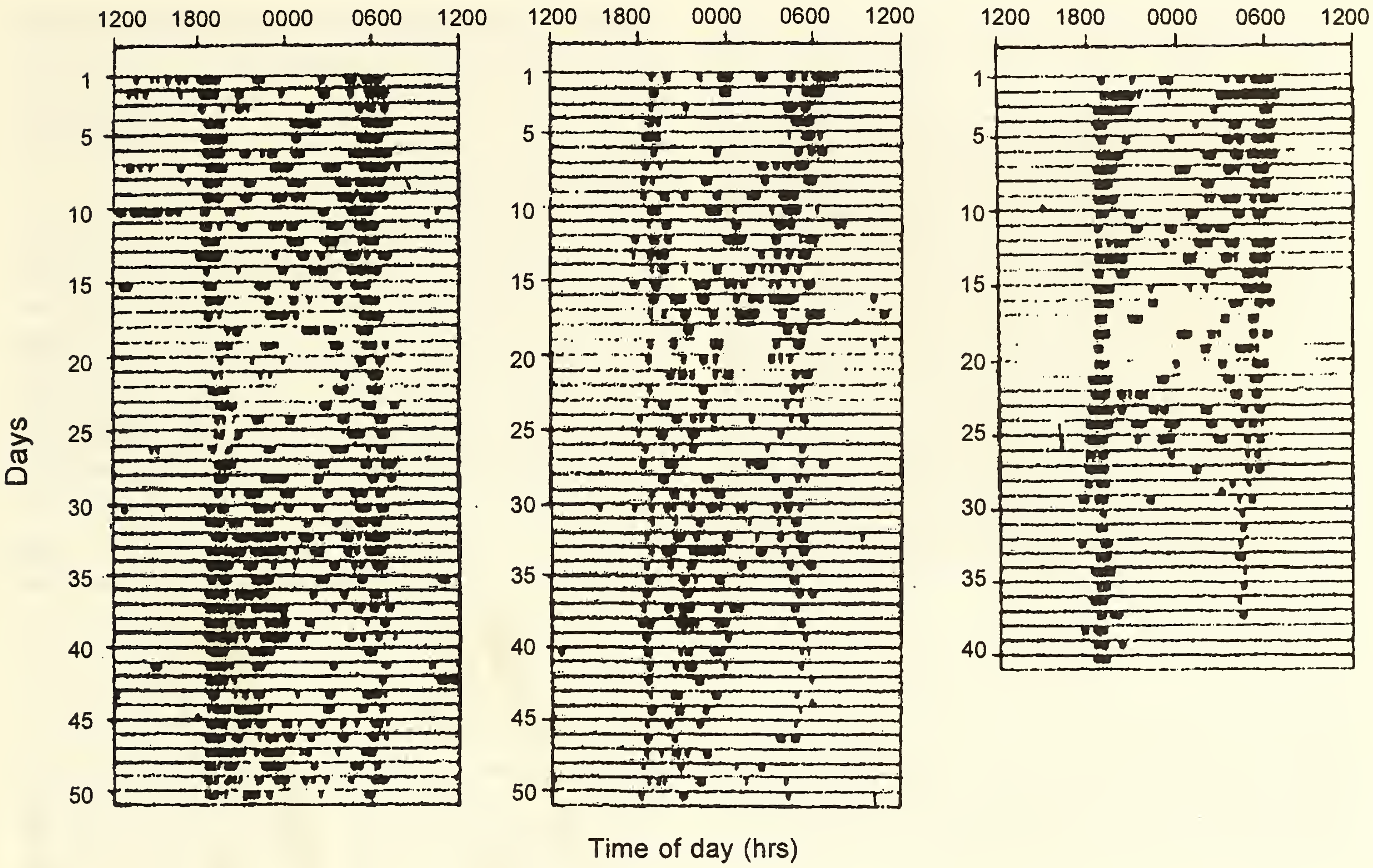


Fig. 12: Actogram showing flight activity patterns of three captive male *Hipposideros speoris* bats (After Marimuthu *et al.* 1981)

nightly activity just when other free flying bats were *returning* to the roost in the early hours of the civil morning.

Please note that, as shown in Fig. 13, the bat started its nightly activity close to 1900 hrs which is near civil sunset time. On a daytime inspection on day 10, it turned out that the cave was not impervious to bird calls (crows and mynas at a nearby watering hole), at night resident crickets stridulated. It looked as if the solitary bat was taking time cues from these acoustic inputs, but I was sceptical of such interspecific acoustic entrainment and we continued the recordings. To our surprise and excitement, the circadian rhythm slipped into a state of free-run (as explained above) from day 11 onwards (as seen in Fig. 13). The obvious interpretation is that birds and crickets cannot entrain the circadian rhythm of this captive bat. These observations led us to another major question. Do these bats need to be told the time by other bats of the same species? In other words, is social synchronisation in *Hipposideros speoris* species-specific?

There have been interesting reports of species-specific entrainment of perch hopping rhythmicity of the common sparrow *Passer domesticus.* Male courtship vocalisations were played back to female sparrows held in continuous dim light for four and half hours in a 24-hour cycle, and the perch hopping, free-running circadian rhythmicity entrained to song/silence cycles (Gwinner 1966). Similar results came in for two other species of birds the same year and these results generated much excitement for their ecological and behavioural implications. However, a year later it was found (Lohmann and Enright 1967), rather unromantically, that cycles of mechanical noise administered by a loud buzzer

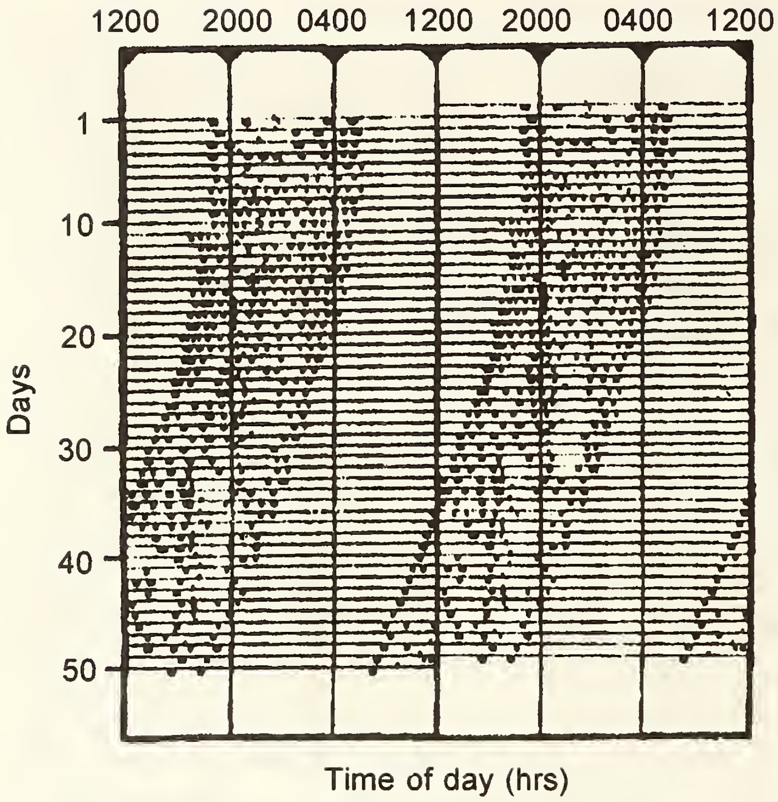
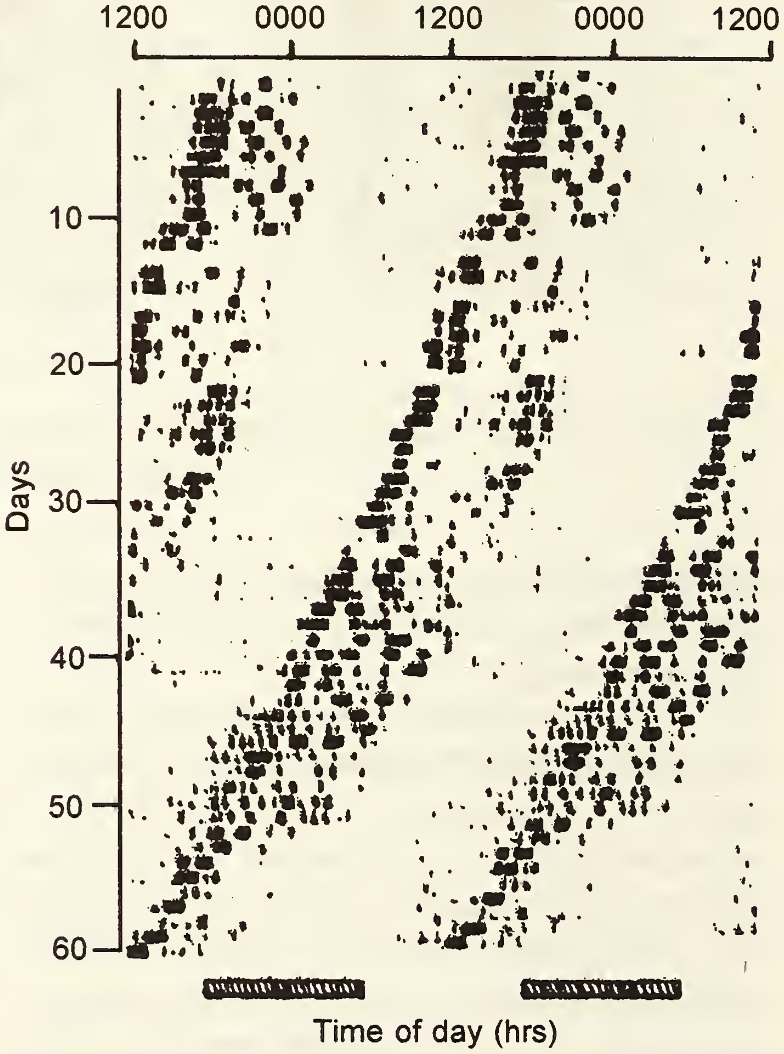


Fig. 13: A double plot of activity/rest patterns of a solitary male *Hipposideros speoris* bat recorded in an empty cave without any conspecifics over a period of 50 days (After Marimuthu *et al.* 1981)

for a few hours in a 24-hour cycle, also entrained the activity rhythms of three species of passerine birds. This is a demonstration of the phenomenon of non-species-specific entrainment of circadian rhythms at its best.

To return to bats, in order to investigate the possibility of species-specificity in social synchronisation of circadian rhythms in bats, we performed an ingenious experiment. We introduced a rank outsider bat, an alien species, a male *Taphozous kachhensis* into the *Hipposideros speoris* cave in the Jain Hills, and recorded its flight/rest pattern while captive. The circadian rhythm of flight/rest activity of the alien could not be socially (or otherwise) entrained by the 550-600 hipposiderid residents (Marimuthu and Chandrashekaran 1983a). The circadian rhythm of the emballonurid *T. kacchensis* impressively free-runs as shown in Fig. 14. We interpreted the results as indicating a kind of communication gap between the hipposiderids and the alien emballonurid. We can back up claims from the results of neurophysiological experiments in which we placed electrodes in the lower colliculus of a *T. kachhensis* bat in the operation theatre and played back the colony vocalisations (including ultrasonic acoustics) of *H. speoris* (using a homemade Lennartz tape recorder of 2-200 kHz range). The emballonurid bat (under mild nembutal narcosis) showed no spike (action potential) responses. The message was not even being heard. These results strongly suggest that social synchronisation of circadian rhythms in microchiropteran bats may indeed be species-



Hatched area at bottom describes hours of exodus activity during early night and returning of the resident, free-flying *Hipposideros speoris* bats.

Fig. 14: Double-plotted actogram illustrating the free-running of the circadian rhythm in the flight activity pattern of an emballonurid bat *Taphozous kachhensis* confined to a hipposiderid (*H. speoris*) cave for 60 days (After Marimuthu and Chandrashekaran 1983a)

specific. The interesting field observation is that, in some places, *H. speoris* and *T. kachhensis* are known to share roosting sites (pers. observ., also Brosset 1962).

We have established for the first time that: 1) the circadian rhythm of a captive bat held in isolation in perpetual darkness free-runs, and 2) in the presence of free flying conspecifics which undertake foraging flights out of the cave and back, the circadian rhythms of captive bats entrain to the 24-hour periodicity of flight/rest of the colony. Thanks to the light/darkness of the natural environment (ubiquitous entraining agents) there are no free-running rhythms out there in nature, except in deep-sea organisms and those living in caves (Koilraj *et al.* 2000). Circadian rhythms are also known to free-run in organisms in the Arctic winter (of perpetual darkness) and summer (of continuous light) (Bünning 1973). We were curious to know how bats dwelling in the darkness of caves and foraging in further darkness of nights would respond to exposure to continuous light — an admittedly artificial condition that these tropical bats never face. Artificial light was created with car batteries and an incandescent bulb inside the *Hipposideros speoris* cave, and the flight activity/rest patterns of three male captive bats, in activity cages placed in the vicinity of the light bulb, were measured. The ambient light intensity at the level of the cages was between 5 to 15 lux. It can be seen from Fig. 15 that the circadian rhythms in the activity/rest patterns in all three bats free-ran (Marimuthu and Chandrashekaran 1983b) with a period > 24 hours. Continuous light lengthens period and perpetual darkness shortens it, in these dark active animals, effects that have been codified in 'Aschoff's Rule' (Aschoff 1960, Pittendrigh 1960). A careful examination of Fig. 15 will reveal two 'conflicting' components. All three bats do stir about briefly during the colony's exodus flight, but lapse into sleep and begin and end activity according to their endogenous circadian free-running schedule with a period >24 hours. The brief arousal during colony exodus coinciding with sunset is called a positive masking effect (Aschoff *et al.* 1982), and the free-run, the true expression of the circadian clock, which is apparently uncoupled from the 24-hour social synchronising inputs, by the artificially created continuous light. In spite of close to ten years of working on the social synchronisation of circadian rhythms in *H. speoris* we are still, quite literally, in

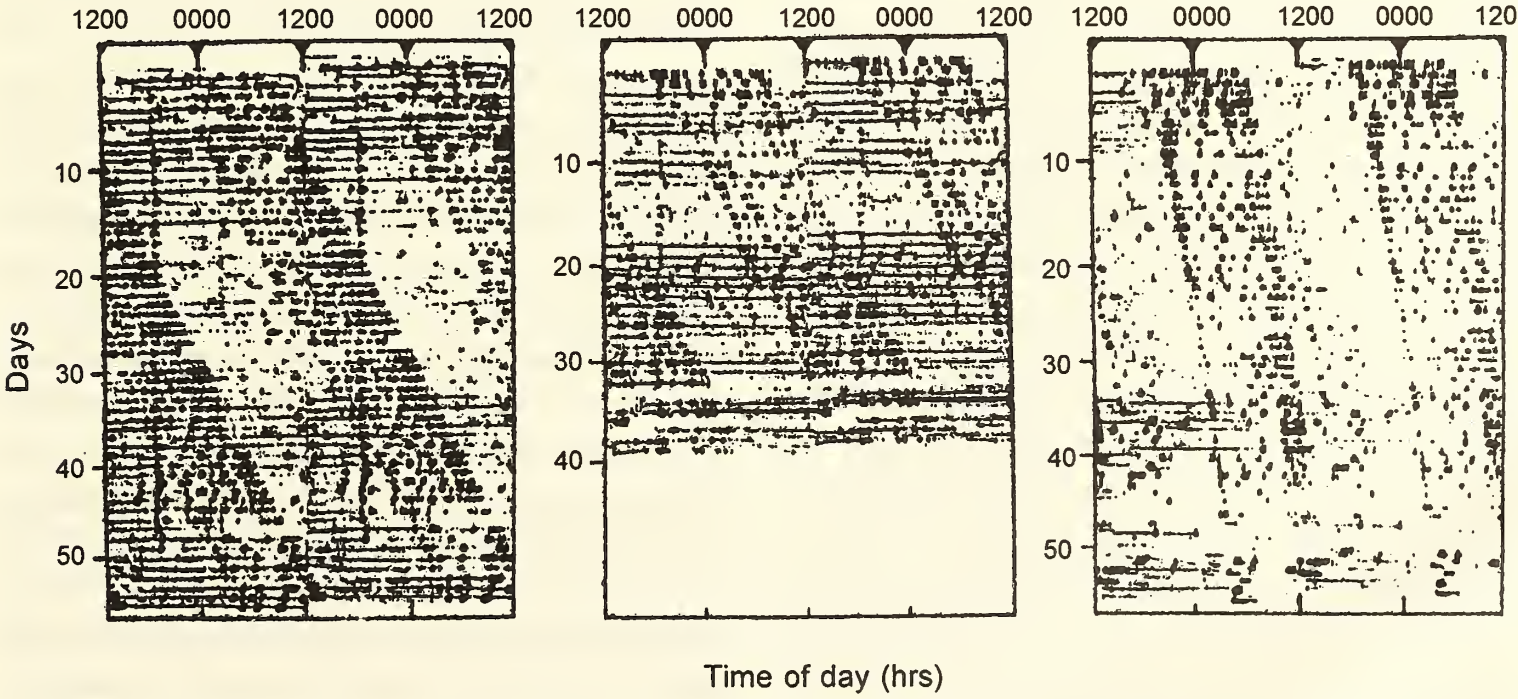


Fig. 15: The flight activity patterns of three captive male *H. speoris* bats for durations of 55 days (a and c) and 39 days (b), registered in LL of 10 to 20 lux (After Marimuthu and Chandrashekaran 1983b)

the dark about the exact nature of the social cues (ultrasonic acoustics? pheromones? wing-flapping noise of free flying bats?) behind this kind of entrainment.

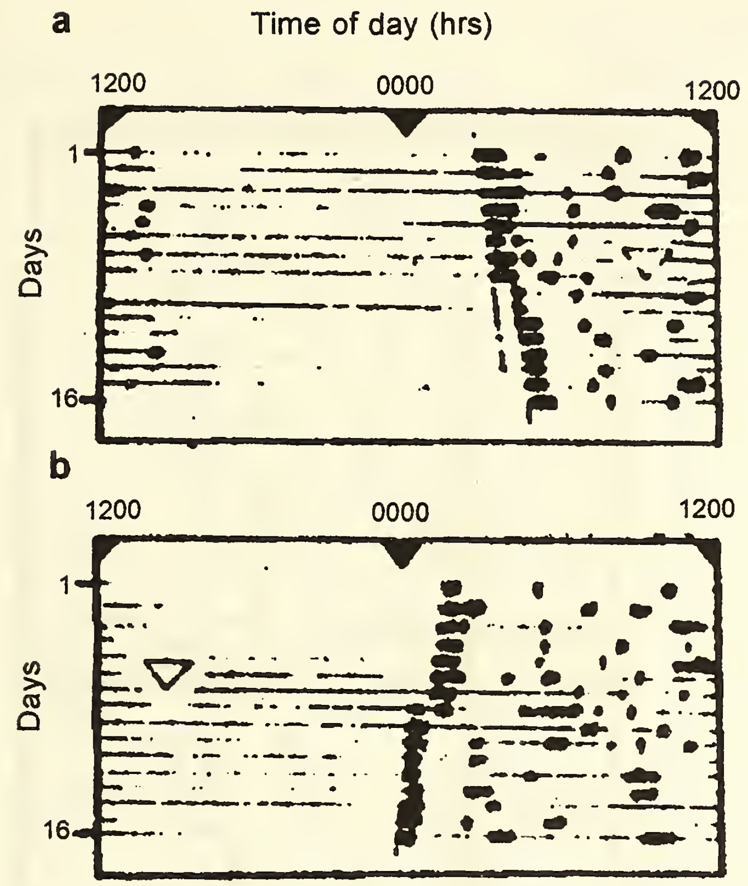
One of the earliest reports to impute social synchronisation among conspecifics was for mice of the genus *Peromyscus* (Halberg *et al.* 1954). Similar effects have been subsequently claimed for blinded mice, male chevrotain antelopes, wolf-coyote hybrids, beaver colonies of *Castor canadensis*, macaques and sexual cyclicity of female mammals (for an early review, see Chandrashekaran 1982). Social synchronisation of circadian rhythms deserves to be better studied, preferably using social insects such as honeybees and ants (Frisch and Aschoff 1987).

A daylight PRC for the circadian rhythm of *Hipposideros speoris*

The 'phase response curve' (PRC) is a plot of the responses of a circadian rhythm in terms of phase shifts to perturbations (of light, temperature, and chemicals) as a function of phase. A vast body of scientific literature has accumulated on this subject. A PRC informs the state of sensitivity of the basic oscillator (biological clock) at any given phase to the zeitberger stimuli (perturbations). Such information cannot be had, for instance, when we record discrete events such as locomotion and rest, which start and end abruptly. There is no clue to the state of the clock during hours of rest when nothing happens outwardly. Further, all external events, both observable and measurable, may be of the nature of the 'hands of the clock'. Pittendrigh (1960) stated that the *Drosophila* PRC reflected the time course and waveform of the basic oscillator. All experimental studies to construct PRCs have been made with fluorescent and incandescent light (Chandrashekaran 1998). We therefore constructed a daylight PRC for the circadian rhythm of the cave dwelling bat *Hipposideros speoris*, employing brief pulses of daylight for perturbations and performing the arduous experiments inside a natural cave. The dimensions of this cave were less cramped (12 x 8 x 2.5 m), with uneven walls, ceiling and floor. The 5 original inhabitant bats (*H. speoris*) were evicted, and the cave was fitted with blinds and lightproof doors. Temperature was constant at 28 ±1°C and relative humidity of 85 ±5% prevailed. Employing methods described earlier, the flight activity/rest patterns were recorded on Lambrecht-KG-Göttingen thermohygrograph drums. The bats were brought to the cave mouth (close to the hinged door) at different phases of the circadian rhythm and exposed to diffuse daylight of *c.* 1000 lux for 15 minutes. Fig. 16 illustrates a typical delay phase shift and a typical advance phase shift of the flight activity, and Fig. 17 illustrates the PRC obtained on many bats. The daylight PRC we obtained resembles those made for other organisms using fluorescent and incandescent light (Joshi and Chandrashekaran 1983).

Daylight dimmer than starlight entrains *Hipposideros* rhythm: I report an accidental finding which we later investigated at some length. This happened in the cave inside which Dilip Joshi had worked out the PRC. Another student, S. Rajan brought in a chart depicting the flight activity of a solitary male *H. speoris* for a period of 47 days under absolute darkness, constant temperature and relative humidity. The activity started at around 1900 hrs, evening after evening, and stopped a little before sunrise. The calculated period length was exactly 24 hours, unheard of in the literature on circadian rhythms. This made me write an eccentric paper, 'An unusual circadian rhythm with a precise 24-hour period' (Chandrashekaran 1981). I philosophised "The law of parsimony dictates that we consider our 24-hour bat as an *isolated* instance of a circadian system quite accidentally possessing a very uncircadian circadian rhythm!"

Then Dilip Joshi brought in 4 or 5 other cases of bats with precise 24-hour periods. To make a long story short, light was apparently leaking in. Careful scrutiny revealed a crack in the uneven ceiling of the cave through which very

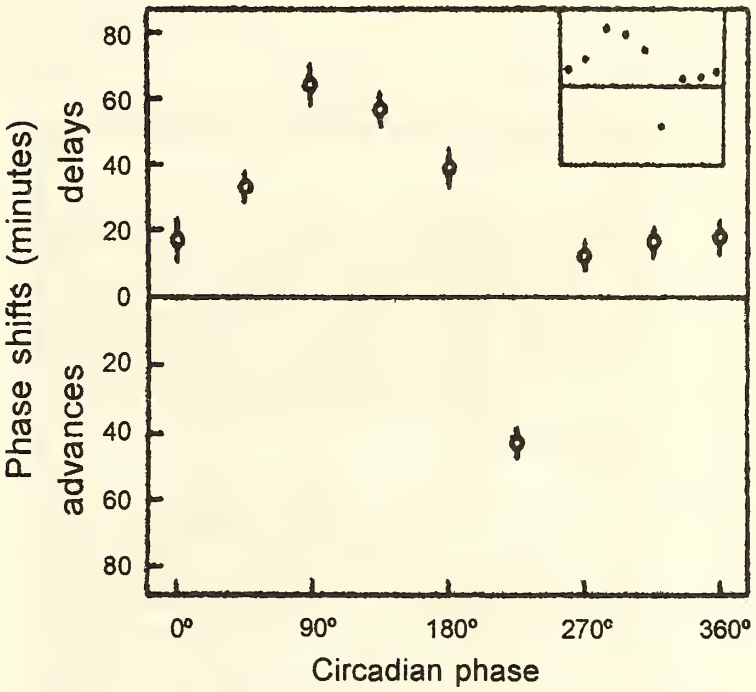


a. Illustrates a delay phase shift of 63 minutes at 90° phase of light exposure.
b. Illustrates an advance phase shift of 42 minutes at 225° phase of light exposure.
∇ = light exposure

Fig. 16: Phase shifts caused in the flight activity rhythm of two male *Hipposideros speoris* bats by 15 mins exposure of the animals held in DD to diffuse daylight of *c.* 1000 lux (After Joshi and Chandrashekaran 1983)

dim light in the range of 0.0001 to 0.0006 lux streamed in. Due to the inclination of the crack the light came in for just *c.* 90 to 100 minutes during midday hours. Light intensity was measured (with a UDT optometer on the log-scale, i.e. time x intensity) where it shone the brightest on the floor of the cave.

Two experiments were performed with 4 and 3 bats. All these bats entrained. Fig. 18 shows the pattern of entrainment of two bats used in the first experiment over periods of 39 days (Fig. 18a) and 35 days (Fig. 18b) respectively, in response to very dim light of 0.0001 to 0.0006 lux illumining the bats for *c.* 1.5 hours. Onset of activity coincided with the local sunset time. Results of



Open circles = Mean; Vertical lines = SD. n = 4 or 5

Fig. 17: PRC obtained for the circadian rhythm in the flight activity of *Hipposideros speoris* in DD inside a cave on several bats, and for a solitary bat (PRC in inset), over a protracted period of 156 days with 15 minutes daylight of *c.* 1000 lux (After Joshi and Chandrashekaran 1983)

the second experiment confirm that the entrainment was indeed effected only by the dim light. Fig. 19 shows entrainment of the flight activity in 2 bats during the first 18 days. Then the light leak was plugged. In one bat the free-run of the rhythm set in immediately (Fig. 19a) with a period < 24 hours, and the other bat continued in the entrained rhythm for 2 weeks before its rhythm free-ran with a period >24 hours (Fig. 19b) (Joshi and Chandrashekaran 1982). An interesting feature of entrainment in this case was that even though the bats experienced exposure to the dim light at midday, the onset of activity coincided with local sunset time 6 to 7 hours later. Obviously, the light pulse in addition to entraining also influences the phase angle. In other words, the bats recognised the dim light to be midday light. We had speculated that this phenomenon might have an adaptive value.

The lowest intensity of light reported in literature as entraining a circadian rhythm (in the

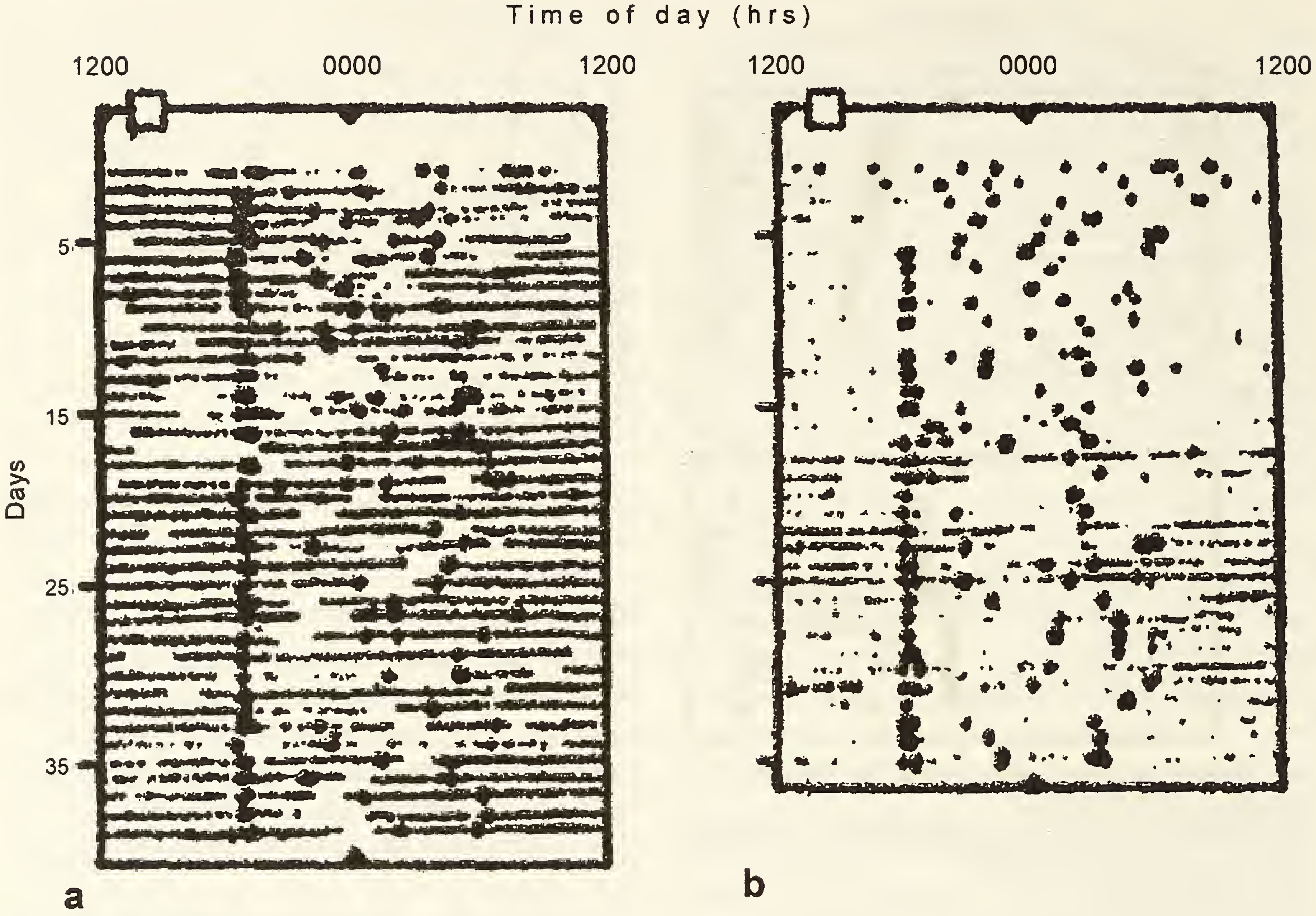


Fig. 18: Entrainment of the flight activity rhythms of two male *Hipposideros speoris* bats inside a natural cave for 39 days (a) and 35 days (b) in response to *c*. 90 mins of dim light of 0.0001 to 0.0006 lux streaming in at midday hours (box at top) (After Joshi and Chandrashekaran 1982)

sensitivity of the median eye of the scorpion *Androctonus australis* L.) is 0.00025 lux shone continuously for 16 hours (Fleissner 1977). It must be pointed out that the actual light intensity at the level of the flight activity cages, positioned approximately 2 to 3 m away from the site of light measurement, was beyond the sensitivity of our optometer. The intensities of daylight that entered the cave were about 5% to 30% of starlight intensity. These are to date the lowest intensities of light implicated in entrainment of circadian rhythms. We have also constructed PRCs for ultra-short light pulses of 0.0625 milliseconds, for the circadian rhythm in the flight activity of *Hipposideros speoris*, which are the shortest light pulses in literature, demonstrated to shift phase (Joshi and Chandrashekaran 1985a).

Spectral sensitivity of the photoreceptors in *H. speoris*: Do the bats have colour vision? We performed a series of experiments to study the spectral sensitivity of the photoreceptors responsible for phase shifting the circadian rhythm of flight activity in the bat *H. speoris*. In nature, these bats exist in a strange paradoxical light-darkness regimen experiencing absolute darkness during the daytime inside natural caves where they roost, and some amount of light (starlight, moonlight) during the night when they forage in the open. They are thus exposed to skeletal pulses of dim twilight of 4-40 lux in intensity, during dawn and again during dusk on the same day, that constitute the major phase resetting stimuli responsible for entrainment by natural light.

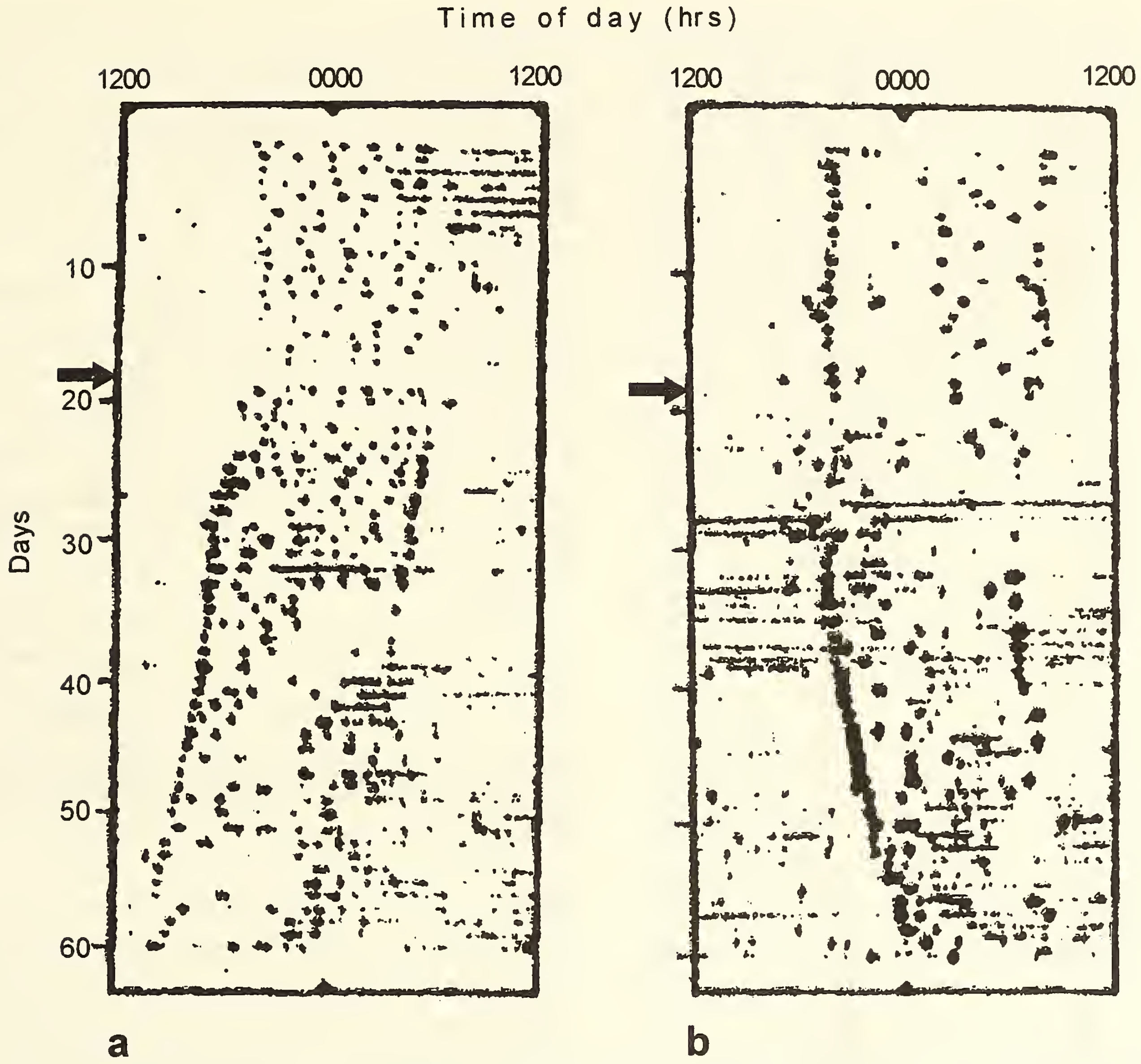


Fig. 19: Pattern of flight activity rhythms of two captive male *Hipposideros speoris* bats inside the DD of a cave for 60 days. Entrainment ensues for 18 days (a) and 33 days (b) in response to very dim light streaming through a crack in the ceiling. The leak was fixed on day 18 (indicated by arrow) (After Joshi and Chandrashekaran 1982)

We have monitored the phase shifts evoked when the circadian rhythms, free-running in constant darkness, were exposed to 15 minute and 2.77 hour pulses of monochromatic light (100 $\mu W/cm^2$) at various phases. Fig. 20 illustrates the flight activity record of a bat in DD for 275 days, exposed at various phases to monochromatic light pulses. The marathon experiment lasted 275 days and the actogram shows long lasting changes in period that followed some phase shifts. For these experiments, four phases were chosen to investigate the wavelength dependent phase shifts, and we reported that light pulses of 430 and 520 nm unequivocally delay (at CT 18 hrs) and advance (at CT 4 hrs) the phases, respectively. It was postulated that there might exist *two* classes of photoreceptors in the retina of *H. speoris*. The S photoreceptors (short wavelength sensitive) having a maximum sensitivity at 430 nm and the M photoreceptors (middle wavelength sensitive) having maximum sensitivity at 520 nm, that mediate delay and advance phase shifts (Joshi and Chandrashekaran 1985b). This is illustrated in Fig. 21. The data presented in the figure was derived from 156 phase responses for 36 bats; for each point at least four measurements were taken.

Prey capture by the false Indian vampire bat: *Megaderma lyra* (Body weight 31-35 g, best hearing frequencies 11-65 kHz)

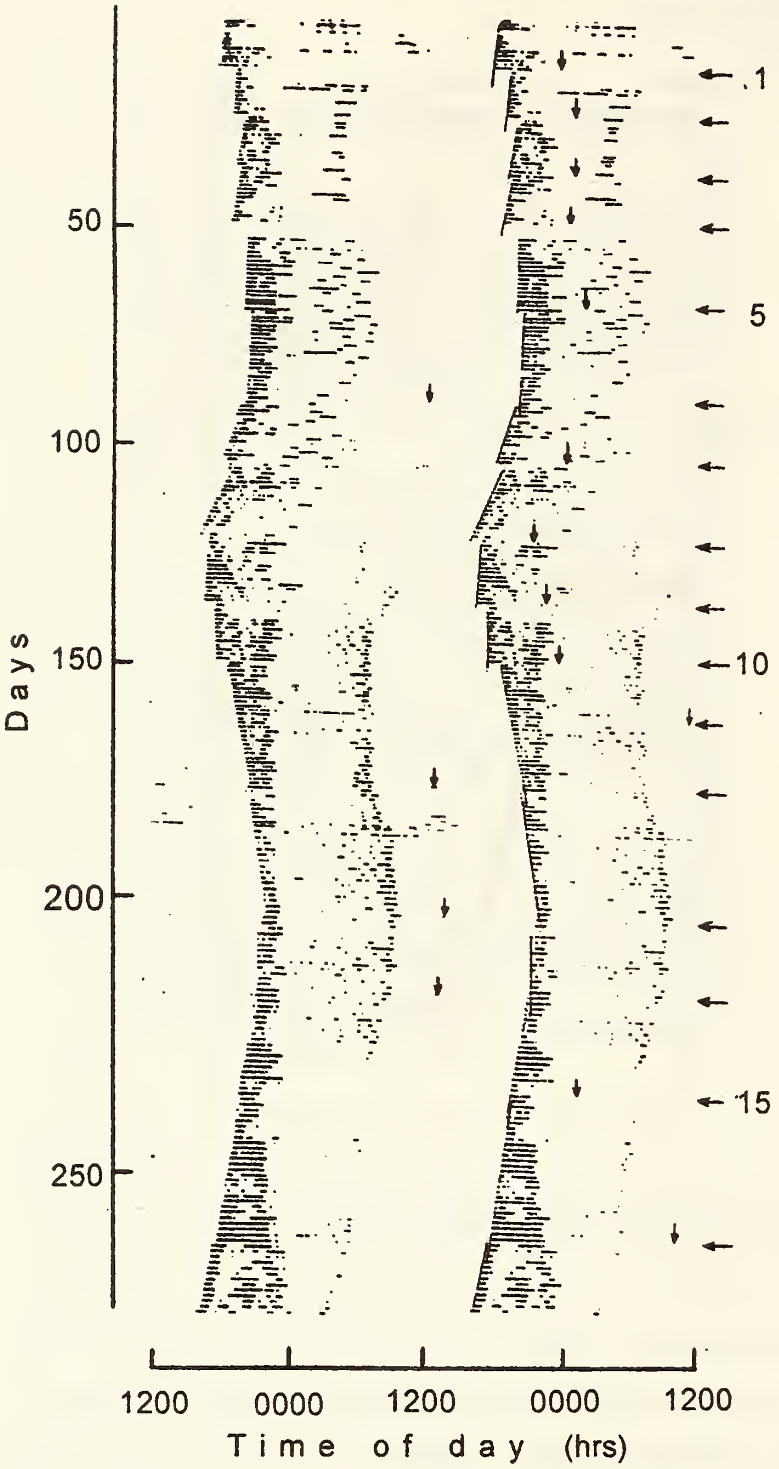
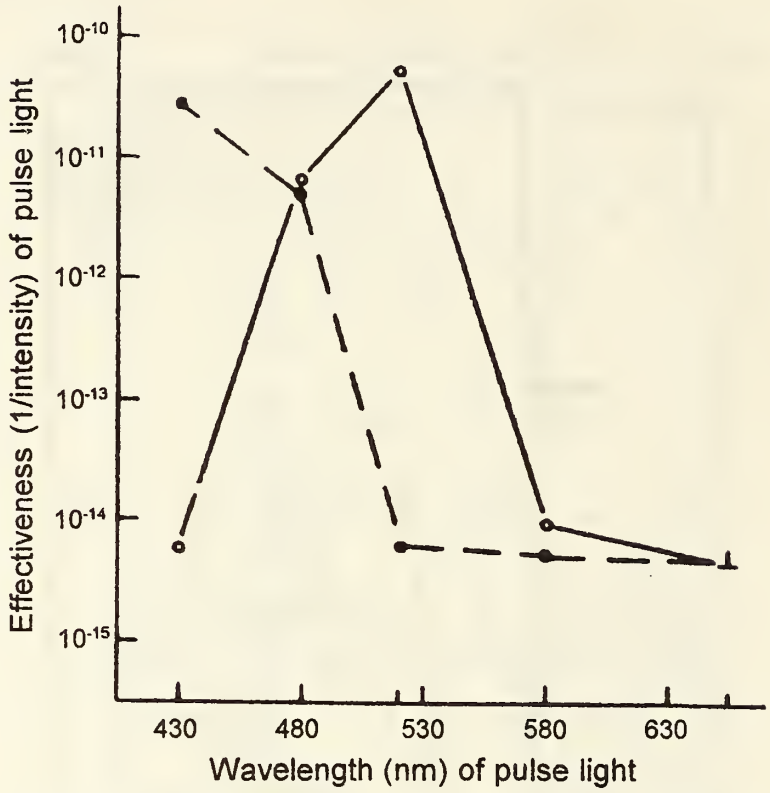


Fig. 20: Flight activity record of a male *H. speoris* bat held in DD exposed to monochromatic light pulses of higher energies of 100 μW/cm² for durations of 2.77 hours given at different phases (pulses 2 to 16). Horizontal arrows to the right indicate the phases at which the light pulses were given (After Joshi and Chandrashekaran 1985b)



Advance phase shifts (CT 4 hrs) = solid line, maximum at 520 nm. Delay phase shifts (CT 18 hrs) = broken line, maximum at 430 nm.

Fig. 21: The spectral sensitivity curves obtained with 15 minute monochromatic light pulses that evoked approximately 50% of the maximal advance and delay phase shifts evoked by white light pulses at CT 4 hrs and CT 18 hrs phases, respectively (After Joshi and Chandrashekaran 1985b)

The biggest colony of the false Indian vampire bat *Megaderma lyra* lived in a very well camouflaged cave, on the southern slope of Nagamalai Ridge to the west of MKU, which was difficult for humans to approach. This bat is unique among Microchiroptera because its diet is eclectic, including small vertebrates, birds, reptiles and mammals. Our German colleagues maintain their colony of *M. lyra*, captured in and around Madurai, in Munich, offering each bat one live mouse a day. In our laboratory, we had at least twelve *M. lyra* at any given time, let loose in the outdoor bat enclosure with a well stocked frog pond (dimensions given under '*Taphozous kachhensis*'. These bats, which are the most ferocious when handled, did their own foraging, feeding on the frogs that jumped out to the edge of the pond, or in water. G. Marimuthu has performed elegant experiments and reported the unusual modes of prey capture in *M. lyra*, on land and in water (Link *et al.* 1986, Marimuthu and Neuweiler 1987).

On land: Six to ten bats were used in the experiment. The bats generally hung from the steel rafters of the outdoor enclosure, visible during night, and inside the darkened wooden enclosure, during day. These bats need 'personal' space but unlike *H. speoris*, *M. lyra* huddle when they are disturbed in their natural haunts or are feeling threatened (Chandrashekaran and Marimuthu 1987). Also unlike *H. speoris*, the *M. lyra* stirred out of the darkened wooden enclosure into broad sunlight and hung from the steel rafters of the enclosure. Marimuthu released medium sized frogs on to the sandy floor of the outdoor cage and made the interesting discovery that only jumping frogs attracted the attention of the bats. If the frogs sat still, the bats did not take any notice of them. The moment a frog jumped, the bats, in threes and fours, swooped down to catch it, but only one of them succeeded in getting hold of the frog by its scruff. The victorious bat stayed for 2-3 seconds on the ground and used its wings to properly position the frog in its jaws. Then it flew up and off, back to its roosting position, to ingest in the next 3-5 minutes the entire frog head first, leaving only the hind legs, in interesting contrast to the tastes of humans in frog consumption (Marimuthu and Neuweiler 1987).

Marimuthu also demonstrated that dead frogs tied by twine and dragged over a sandy surface are promptly captured, but not dead frogs that are noiselessly dragged over a smooth glass pane over a thin sheet of water. It is clear that this gleaner was not detecting the motion of the prey but was listening to the "zic" noise of 10-15 kHz that jumping frogs made. This mode of prey capture by gleaners listening to the rustle of scampering prey on the ground, without resorting to echolocation, has been called 'passive acoustic localisation'.

In water: There are some species of bats that preferably hunt over rivers, lakes, and marine coastlines and take prey from the water surface. Such species are *Noctilio leporinus*, *N. labialis*, *Megaderma lyra* and *Myotis* spp. On field visits at night time, in areas rich in ponds and small waterbodies in south Madurai, one often noticed *Megaderma lyra* silently and swiftly fly past at a mere height of *c.* 1 m, obviously listening for scampering prey or jumping frogs. Some species of bats that hunt over ponds, rivers and lakes have enlarged feet with which they scoop up small fishes and arthropods from the water surface. An ideally smooth water surface would act as an acoustic mirror, making it difficult for echolocating bats to receive an echo. Water ripples and objects protruding from the surface create a kind of texture. Hunting *M. lyra* seem to detect the protruding snouts of stationary frogs in water, in this manner. Ultrasonic recordings indicate that the false vampire actively echolocate snouts of frogs, most of which remained strangely motionless (Marimuthu *et al.* 1995). While the bat hovers over the water, its flapping wings fan the air, which creates ripples in the water all around the snout of the frog below. *Megaderma lyra* presumably detects, using ultrasonics and echolocation, the outward progression of ripples *vis-à-vis* the motionless central protrusion of the snout of the frog. As soon as the hunting bat splashes into the water, the other frogs dive deeper into the pond and swim to safety.

The role of eyes in echolocating bats: The advantages of echolocation and the glamour surrounding the subject is such that extensive work has been carried out on this aspect (Neuweiler 1990). But surprisingly little is known about the precise use of the bats' eyes in vision and prey capture. A book devoted entirely to bats (Altringham 1996) makes only one reference (Bell 1985) to the function of vision in prey capture. It is common knowledge that hearing in microchiropteran bats is much more efficient than seeing. Morphologically, the auditory regions of the brain of insectivorous bats are disproportionately large compared to the optic regions. The auditory regions of the brain are specialised to receive, process, store and retrieve information about the environment on the basis of soft echoes.

We have not conducted specific experiments to investigate the role of the eyes of Madurai bats in landing or prey capture. The Madurai bats forage as efficiently on new moon nights as they do during a lunar eclipse (Usman *et al.* 1980). We, however, have evidence that *Hipposideros speoris* and *Rhinopoma hardwickei* did forage on insects in the pitch-black darkness of their caves. This often happened when there was heavy rainfall outside, coinciding with sunset and the bats could not fly out. Hordes of insects were driven into the caves by the gusts of wind. Link *et al.* (1986) have reported that *Rhinolophus rouxi*, *Hipposideros speoris* and *H. bicolor* approached and seized dead cockroaches held by forceps, when these were artificially vibrated. This indicates that any oscillating movements and not specific aspects of wing beating were the key stimulators for catching-behaviour in all three species. Once, Marimuthu was feeding bats held captive, in activity cages, 40 m deep into the Jain Hills cave. He was holding the live cockroaches with the aid of forceps. The elytra, wings, legs and innards of the insect had been removed. Even after this operation the cockroach usually wriggled between the tips of the forceps. On one occasion, a free flying *H. speoris* wrenched a wriggling cockroach off the forceps. On scanning the ceiling of the cave with a torch emitting 'safe' light of >630 nm, a male bat was found hanging from the ceiling, chewing the cockroach. This prey capture in absolute darkness was obviously accomplished solely by means of echolocation, in which *H. speoris* employs CF/FM signals of 5-10 milliseconds of pure tone of 132 kHz terminated by a brief FM sweep (Neuweiler *et al.* 1988). On the basis of these findings I conclude that the tiny eyes of echolocating bats such as *H. speoris* and *H. bicolor* are not efficient in prey capture, and may act as photoreceptors for 'sampling light' recurrently every 24 hours, thus entraining their circadian clocks. Similar views have been expressed by other bat researchers (Kunz 1982).

Mother-infant relations in *Hipposideros speoris*: Bats are altricial, with newborn pups being highly dependent on the mother. Females lavish a lot of attention on their young. *H. speoris* mothers either left their young behind in a crèche in the cave or carried them to the foraging areas. At first it appeared that there was no correlation between the age of the young and the frequency with which it got carried around by the mother (Marimuthu 1988). A more detailed subsequent study in our laboratory and statistical analysis (Kolmogrov Smirnov test, $p = 0.05$) on the patterns of mothers: i) carrying their young and ii) leaving them behind as a function of the size/age of the young, revealed that the two distributions (Fig. 22) differ significantly and that more bat pups are left behind as they become larger (Radhamani *et al.* 1990).

The young that were left behind in the cave clung on all fours to the ceiling and scarcely moved. The mothers often returned before midnight and retrieved them. During retrieval, the mother moved towards her infant, gently touched it with her forearm and presented her ventral surface, especially the pubic region, moving in such a way that the young could hold on to the dugs with its teeth. Then the infant bat let go of its perch on the rock ceiling, nestled under the wing membrane of the mother, and oriented towards the mammary glands to suckle. When satiated, the young fluttered its wings and often hung from the neck of the mother. During the day the volant young bats routinely hung from the necks of the mothers and as the observer moved closer, they briefly flew away, to reunite with the mother and assume the same posture in 10 to 15 minutes (Marimuthu 1988). In this posture, the young have been seen to stretch their wings and simulate flight. I am not sure if any other species of Microchiropteran bat infants, in the tropics or temperate climes, use their mother's neck as a perch.

Marimuthu (1988) has also reported, from experiments performed under natural conditions and under semi-natural conditions in the outdoor

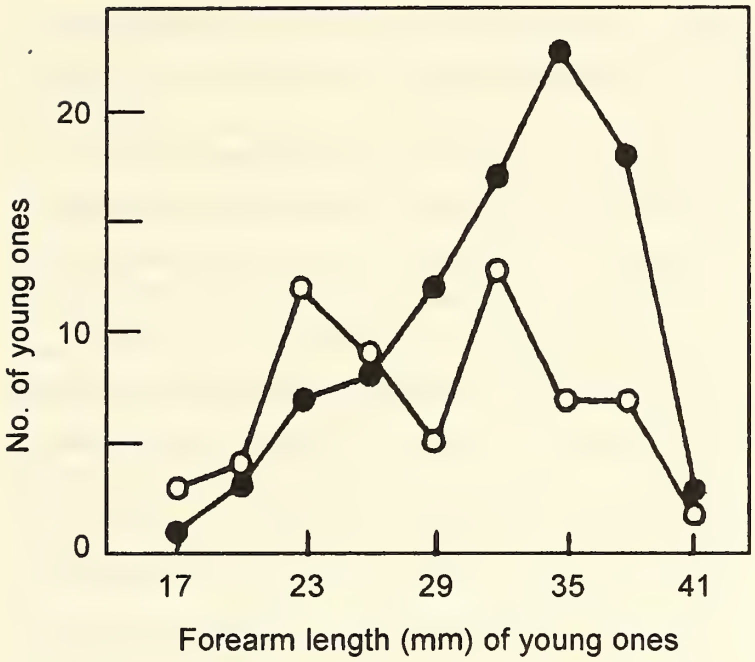


Fig. 22: The pattern of mother bats carrying their young (hollow circles) to the foraging areas, or leaving them behind in the cave (filled circles) as a function of the size (which corresponds to age) of the infants (After Radhamani *et al.* 1990)

bat enclosure, that female *Hipposideros speoris* identify their own pups. In an experiment performed close to the mouth of the Jain Hills cave, he placed six pre-volant pups on a cool rock. Mother bats returned in the pre-dawn hours and exhibited hovering and circling flight and possibly emitted trains of ultrasonic pulses of 134 kHz directed at the pups. The pups became agitated as though they were responding to the hovering mother bat, and raised their heads and emitted audible multi-harmonic squeaks (Habersetzer and Marimuthu 1986). Infant vocalisations attracted the mothers, who flew towards them and alighted close to them. The pups tried to cling to *any* bat mother but the mother bats snuggled closer and retrieved their own young. Mothers located their infants even when the juveniles were displaced from where the mothers left them. Behavioural experiments under both natural and captive conditions showed that the sound emission of the pups attract the mothers, but may not contain sufficient clues for them to correctly identify their own from among a group of squeaking young ones. The nuzzling of the mother among the pups is indicative that olfactory means also mediate final identification and retrieval (Gustin and McCracken 1987, Habersetzer and Marimuthu 1986, Marimuthu 1988). On many occasions I had observed infants of *Rhinopoma hardwickei* and *H. speoris* fall to the ground and emit faint but audible vocalisations, to be retrieved by obviously their own mothers. So there can be no doubt that vocalisations are the primary cue for infant recognition. Isaac and Marimuthu (1993b) have reported their accidental discovery of how a mother pygmy bat *Pipistrellus mimus* responded to the vocalisations of a one day old infant. A maternity colony of *Pipistrellus mimus* roosted for several years in a sleeve-like tunnel 1.3 m wide, 0.85 m high and 24 m long with a right-angled bend and just one entrance on the western side of the Department of Animal Behaviour and Physiology building. A small colony of 18 *Rhinopoma hardwickei* had also chosen this tunnel as a daytime roost. Suthaakar Isaac separated a one day old infant bat from its pipistrelle mother after tagging her, and took the infant to his work bench nearly 70 m away from where the mother bat was roosting on all fours. *Pipistrellus* spp. never carry their young to foraging grounds. The infant separated from its mother was emitting ultrasonic distress and isolation calls continuously, in the range of 30 to 80 kHz measured using a Mini-2 bat detector (Ultrasound Advice, UK). The time of day was 1800 hrs to 1900 hrs when the sun sets and bat colonies stir out. The mother was apparently flying around, heard the isolation calls of her infant and in response flew into the room through an open window and alighted on the infant, covered it with her wings, lifted it up and flew away. The entire rescue operation apparently lasted only a few seconds (Isaac and Marimuthu 1993b). Other researchers have also reported that bat mothers respond to calls of their own young (Balcombe 1990).

We commented in one of our papers (Radhamani *et al.* 1990), "The present study deals with mother-young relations in a cave-dwelling insectivorous bat *Hipposideros speoris* and explains how the mother bats carry even their volant young to their foraging areas in order *to acquaint them* with the topography and foraging strategies", and later in the same report, "...more young ones are left inside the cave as they become larger". These two statements make, in fact, contradictory claims. Though volant subadult *H. speoris* can produce and hear CF/FM sounds (127-138 kHz) (Habersetzer and Marimuthu 1986) in the adult range, they face *opposite* the direction of the flight path of the mother while being carried. Subadult *Hipposideros* may use ultrasonics to form an acoustic picture of the interior of the cave and the immediate environment (Marimuthu 1988). In the case of *Megaderma lyra*, the mothers even carry infants which are nearly their own size. These bats are known to have secondary night time roosts. In Madurai, many of the *M. lyra* bat mothers used a cowshed as a night time roost and left their infants on the ceiling.

BREEDING PERIODICITY OF INSECTIVOROUS BATS

Breeding pattern of *Hipposideros speoris*: Brosset (1962a) writes of the breeding pattern of *H. speoris* of the Poona/Khandala region "The periodicity is absolutely strict for this species, and all females deliver together in May. The first to do so were observed around 5th May, and the last around the 25th of the same month". In Madurai, there are two peaks of breeding in *H. speoris*, the first and less pronounced peak in May and the second in November, which is how Radhamani (Radhamani *et al.* 1990) could make her observations on *Hipposideros* mothers carrying infants from August to December 1989. G. Marimuthu's detailed work on mother-infant interactions in this hipposiderid bat are based on observations made from December 1977 to February 1979 and November 1980 to February 1981 (Marimuthu 1988). Since a single young is the rule for most species of bats, we can only conclude that there are female *H. speoris* that bear young ones around May and other females that bear young around September/October. Almost all species of bats studied by Brosset (1962a, b, c, 1963) had a very narrow period of parturition. This is also the case in Madurai in the breeding pattern of *Hipposideros bicolor*, which often shared the same cave as *H. speoris*. All young of *Hipposideros bicolor* were born in May. The May peak is the typical breeding pattern to the north of the equator, and the November peak to south of the equator. Professor Aschoff (1913-1998) in personal conversations had often told me that he believed that the "biological equator" might be around eight degrees north of the geographical equator. Madurai interestingly is 9° 58' north of the equator.

Breeding pattern of *Pipistrellus mimus*: The vespertilionid bat, *Pipistrellus mimus* Wroughton, is a commonly occurring and widely distributed bat in India, except in mountainous regions. It is physically the smallest species of bats of India. It is eclectic in the choice of roost sites and lives inside caves, even in small depressions in rocks, cracks, crevices, buildings, inside thatches, tree holes and even in letterboxes. Adults weigh 3.9 ±0.4 gm (n=19) and the forearm measures 27.6 ±1.1 mm (n=26). A group of 20 members of *P. mimus* colonised the tunnel in our departmental building described earlier. Adult females and infants roost in groups, and adult males roost singly throughout the length of the tunnel. The study was carried out over one whole year, from May 1990 to May 1991. Observations were made during the day as well as the night, using a torch light with a red filter (>610 nm). The reproductive condition of every female was noted at each observation. In pregnant females, the embryo was detected by palpation and lactating females were easily identified by the presence of well-developed mammary glands. The young were also tagged. Infants with fresh umbilical cords were noted as being one day old. The time interval between the first parturition in the batch until the last parturition denotes a *cycle* of breeding, somewhat confusingly called breeding "season" in our publication (Isaac *et al.* 1994).

Gopalakrishna *et al.* (1975) reported that *Pipistrellus mimus* was a "continuous breeder". Suthaakar Isaac, a Ph.D. student of G. Marimuthu, studied the breeding patterns of this vespertilionid as a part of his research programme. It soon became apparent that parturition in this bat occurs in four distinct and discrete cycles in a year as shown in Fig. 23. The first cycle of breeding lasted from July 5-14, 1990 (n=6); the second cycle lasted from September 14 to October 30, 1990 (n=8); the third cycle lasted from December 21, 1990 to February 23, 1991 (n=8); the fourth cycle lasted from March 23 to April 11, 1991 (n=3) (Isaac *et al.* 1994). *P. mimus*, unlike other microchiropteran bats of southern India, gave birth to twins. Females gave first birth to twins at the minimal age of 103 days. Possibly facing high mortality rates, this bat species would have to increase the rate of reproduction. Dead infants were often seen on the floor below the daytime roosts of this bat. Since the mother bat does not carry her young, the rate of predation at the roost may also be higher than that in other bats. It is also a behavioural oddity that *P. mimus* bats are the earliest to fly about at dusk, and the last to return to the roost at dawn, thus exposing themselves twice in 24 hours to visual detection by predators (Isaac and Marimuthu 1993a) such as the black-shouldered kite *Elanus caeruleus.* Their flight activity pattern is crepuscular. We have, however, never witnessed any birds of prey capture a bat. We have confirmed that the same female bats underwent successive pregnancies and parturitions. Our results imply that *P. mimus* is the most prolific breeder among the microchiroptera. It would be interesting if similar studies as ours (Isaac *et al.* 1994) are undertaken for other organisms that are often claimed to be "breeding continuously in the tropics."

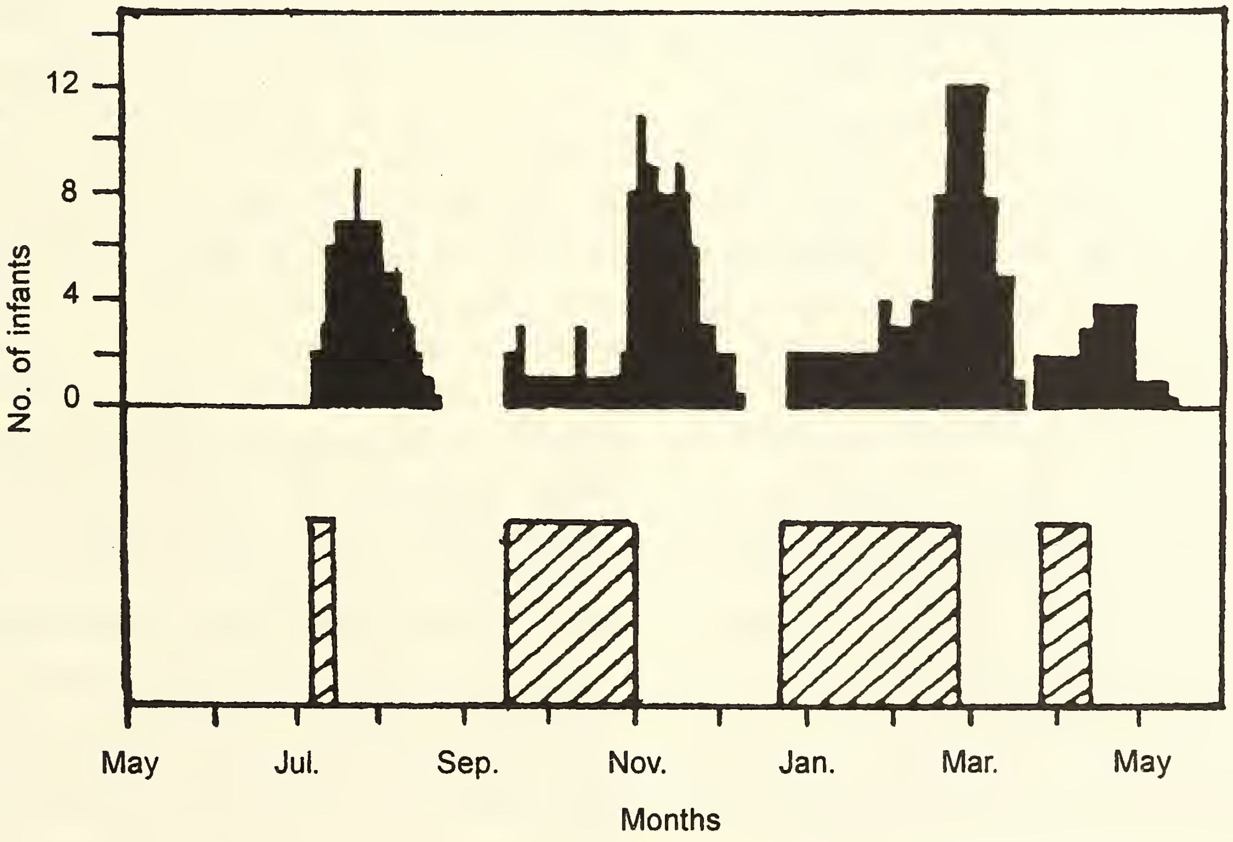


Fig. 23: The four breeding seasons of *Pipistrellus mimus.*
The upper panel represents number of infants from newborn to pre-volant stages, found in the tunnel. The striped areas in the lower panel indicate durations of parturition (After Isaac *et al.* 1994)

GENERAL REMARKS

Personally for me, there remain many unsolved puzzles in the bats I studied. Inside the cave of Jain Hills I noticed, at around 1400 hrs to 1600 hrs, how still the colony of *Hipposideros speoris* became. No bats flew around, even the restless circular movements of the heads of the bats had substantially abated, and it looked as though the bats were indeed in deep sleep. At such times if my movements happened to cause the slightest displacement of a smooth pebble under my feet, the ensuing muffled noise made a hundred bats jerk up in alarm. This 'alertness in sleep' is perhaps an adaptation against predators like the smoothly gliding snakes. Dilip Joshi often brought to the laboratory the sloughed skin of big snakes, which he found inside the cave. The cave was also visited by bandicoots, and we had lost at least one experimental male *H. speoris* to these nightly predators. There were also barn owls and owlets at the cave mouth. I had on one occasion, during our field ethology work on foraging, noticed what might have been a barn owl, capturing a bat. Interestingly, the same *H. speoris* bats, ultra-sensitive to small noises within the cave, flew later in the night around 2000 hrs in the central bus stop of Madurai or in the noisy railway station. The hissing of the engines and the throngs of passengers did not appear to bother the hunting hipposiderid bats. This suggests that there is a heightened threshold sensitivity to audible sound when bats are on the wing. This may also explain why the 'best hearing frequencies' of insectivorous bats have such a restricted band, often excluding sounds audible to humans. Similarly these shy creatures, which avoid the brightness of the sky on full moon nights and fly under canopy cover, forage on swarms of insects drawn to bright sodium-vapour streetlights.

All the species of insect bats that we examined showed roost fidelity, with the exception of *Tadarida aegyptiaca* (body weight 22 to 24 g). This bat is a strong flier that preferably forages at considerable heights of 15 to 20 m above the ground, well over the canopy and ponds. A colony of *c.* 2,000 bats lived in crevices and cracks of a vertical rock on the northern slope of the Jain Hills. They were very noisy, squeaking in chorus, a little before the onset of the evening foraging flight and were difficult to observe. We had planned to monitor activity/rest patterns of this bat also, but were surprised, when we arrived at the site of the colony one evening not a single bat was to be seen. No other bat colony in the Madurai region had vacated its roosting site as *T. aegyptiaca* did. A few weeks later we were informed that some bats had returned. In view of the inconvenience involved in studying the behaviour of this bat roosting in the narrow crevices of the rock at a height of 50 to 70 m, we decided not to continue with our observations on *T. aegyptiaca*.

I have left out much of our laboratory experimental findings on light-induced PRCs made for the circadian rhythms of *Taphozous melanopogon,* and *T. kachhensis* and *H. speoris* to avoid unnecessary technical details. We had reported that the circadian rhythm in activity-rest cycles free-runs in dim light of 5 lux and responds to dark breaks of 2 hours and 4 hours, with advance and delay phase shifts as a function of phase experiencing the 'blackout'. Similarly, phase shifts are also caused by light pulses of 15 minutes and 1000 lux given at different phases. We reported for the first time for any model system (Subbaraj and Chandrashekaran 1978), that the time course and waveform of phase response curves obtained from experiments using pulsed light and pulsed darkness are mirror images of each other. The idea of reviewing our studies was to impart a flavour of the kind of work my students and I had been doing on insectivorous bats, among other objects, at the MKU for two decades. Many of the observations reported here were also first reports of their kind, when they were made. The ecology of roosting sites, site fidelity and social interactions of some of these bats were the most fascinating facets for me.

ACKNOWLEDGEMENTS

The kind of research described here could not have been carried out without the enthusiastic participation of venturesome students like R. Subbaraj, G. Marimuthu, K. Sripathi, Dilip Joshi and K. Usman. I thank Dhanashree Paranjpe for helping me with the figures. I thank Professor Hubert Markl for encouragement and the gift of a jeep, when he was Vice-President of the Deutsche Forschungsgemeinschaft, which enabled more comfortable travel and transport of some equipment to rugged cave sites. The Alexander von Humboldt-Stiftung donated equipment and the UGC, DAAD, DFG and the Alexander von Humboldt-Stiftung enabled me to visit universities in Germany for six weeks every year between 1979 and 1991. The UGC, CSIR and DST financially supported my researches at the MKU, while its School of Biological Sciences, thanks to its founder Professor S. Krishnaswamy (1926-1988), became a supportive environment for teaching, thought and exciting experiments for two decades. I thank an unknown referee for suggesting changes that improved readability considerably in the final version of this manuscript.

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Appendix I: Breeding periodicity in the Madurai bats

Megaderma lyra	:	March/April/May.
Rhinopoma hardwickei	:	April & November.
Hipposideros speoris	:	Through the year with a November peak.
Hipposideros bicolor	:	April/May.
Taphozous melanopogon	:	April.
Taphozous nudiventris kachhensis	:	October.
Cynopterus sphinx	:	March/April/May/June/July.
Rousettus leschenaulti	:	March/April/May/June/July.

Pipistrellus mimus	:	First cycle: July 5-14, 1990 (n=6);
		second cycle: September 14 to October 30, 1990 (n=8);
		third cycle: December 21, 1990 to February 23, 1991 (n =8);
		fourth cycle: March 23 to April 11, 1991 (n=3)
		(Isaac *et al.* 1994).

■ ■ ■

TAIL LENGTH IN ENIGMATIC NORTHEAST INDIAN MACAQUES AND PROBABLE RELATIVES

(*With four text-figures*)

JACK FOODEN[1]

Key words: Arunachal Pradesh, *Macaca assamensis*, *Macaca thibetana*, range extension, subspecific contact zone, tail length variation

Recent sightings in western Arunachal Pradesh, Northeast India, of macaques with tail proportions similar to those in *Macaca assamensis assamensis* apparently extend the known range of this subspecies *c.* 400 km westward along the Lesser Himalaya, across the great bend of the Brahmaputra river. The contact zone between *M.a. assamensis* and *M.a. pelops* apparently is at *c.* 2,000 m along the slopes of the Lesser Himalaya west of the Brahmaputra river, in Arunachal Pradesh and possibly also in adjacent Bhutan.

INTRODUCTION

Macaca assamensis and *M. thibetana* are closely related species that inhabit contiguous areas in southern and eastern Asia (Fig. 1; Fooden 1988, p. 19); despite their close relationship, these two species differ strikingly in tail length. Recently, Choudhury (1998, p. 7; 2000, p. 14) conducted field work in a previously unsurveyed area in Northeast India and observed monkeys that obviously belonged to the *M. assamensis* - *M. thibetana* group, but in which tail length differed from what previously would have been expected in that area. The purpose of the present paper is to consider Choudhury's new information in the general context of tail length variation in *M. assamensis* and *M. thibetana* (see Appendix).

GEOGRAPHIC DISTRIBUTION AND TAIL LENGTH VARIATION IN *M. ASSAMENSIS* AND *M. THIBETANA*

Macaca assamensis includes two recognised subspecies, *M.a. pelops* and *M.a. assamensis,* which differ in tail length (Fig. 1). The known geographic distribution of *M.a. pelops* is narrowly restricted to the Outer and Lesser Himalaya from central Nepal (83° 36' E) eastward to northeastern Assam (94° 25' E) (Fooden 1982, p. 4; Choudhury 1997, p. 37). The known geographic distribution of *M.a. assamensis* is much more extensive, encompassing lower and middle mountain ranges in continental Southeast Asia, from *c.* 30° N in Xizang (earlier Tibet), China, to *c.* 15° N in Thailand and Laos (Fooden 1982, p. 5). Prior to Choudhury's (1998, p. 7; 2000, p. 14) recent research, the gap between the easternmost Himalayan record of *M.a. pelops* (94° 25' E) and the westernmost known Himalayan record of *M.a. assamensis* (95° 45' E) was *c.* 175 km wide. *Macaca thibetana*, in which no subspecies are recognised, is broadly distributed in eastern China, from *c.* 25° to 33° N and from *c.* 102° to 120° E (Fooden 1988, p. 2).

The following summary of tail length variation in *M.a. pelops*, *M.a. assamensis*, and *M. thibetana* focuses on the ratio of tail length to hind foot length (T/HF) in adult males, which is the only relevant information available concerning the newly observed monkeys in Northeast India; however, tail length variation in adult females and immatures in *M. assamensis* and *M. thibetana* is generally similar to that in adult males (Fooden 1988, pp. 9, 10). T/HF in adult males clearly declines progressively in *M.a. pelops*, *M.a. assamensis*, and *M. thibetana* (Fig. 2). In *M.a. pelops* adult males, T/HF values (mean ±SD, extremes) are 1.86 ±0.109, 1.73-2.07, n = 8; in *M.a. assamensis* adult males, these values are 1.26 ±0.127, 1.11-1.56,

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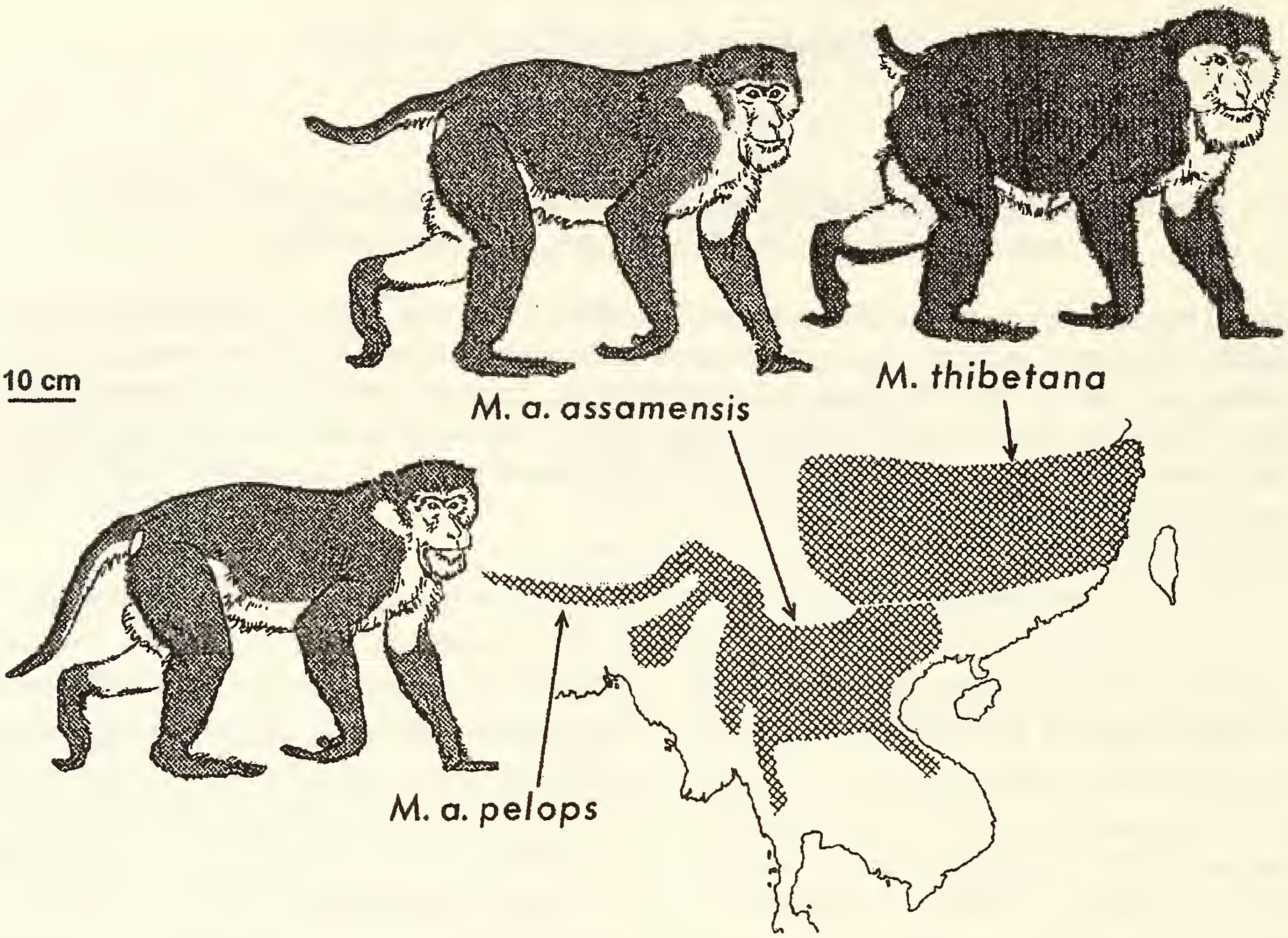


Fig. 1: External characters in adult males and geographic distribution of *Macaca assamensis pelops, Macaca assamensis assamensis* and *Macaca thibetana*; slightly modified from Fooden (1988, p. 4; cf. Fooden *et al.*, 1994, p. 623)

n = 21; and in *M. thibetana* adult males, these values are 0.41 ±0.077, 0.33-0.54, n = 7. Within each of these three taxa, no consistent pattern of geographic variation in T/HF is evident (Fig. 3).

TAIL LENGTH IN NEWLY OBSERVED NORTHEAST INDIAN MACAQUES

Choudhury (1998, p. 7; 2000, pp. 6, 14) observed macaques with unexpected tail proportions in November 1997 at Piri La (27° 07' N, 92° 26' E), western Arunachal Pradesh, Northeast India. At this locality, three troops of monkeys were encountered in temperate broadleaf forest at 2,000-2,700 m elevation; troop size, determined for two troops, was >15 and 21. In one of these troops, Choudhury was able to sketch the dominant adult male and to sketch and photograph one of two subordinate adult males (Fig. 4). Although circumstances did not permit external measurements to be taken, Choudhury's sketches provide a basis for provisional estimation of T/HF in these two adult males; tail length is also clear in Choudhury's (1998, inside front cover) colour photograph of the subordinate adult male, but, unfortunately, the monkey's hind feet are obscured by foliage in this photograph, which therefore precludes its use for calculation of a second estimate of T/HF in this monkey. From the available (albeit suboptimal) evidence of Choudhury's sketches, T/HF in the dominant male is roughly estimated to be 1.2, and T/HF in the subordinate male is roughly estimated to be 0.8 (see Appendix).

Sightings of macaques said to have tail proportions similar to those of the Piri La

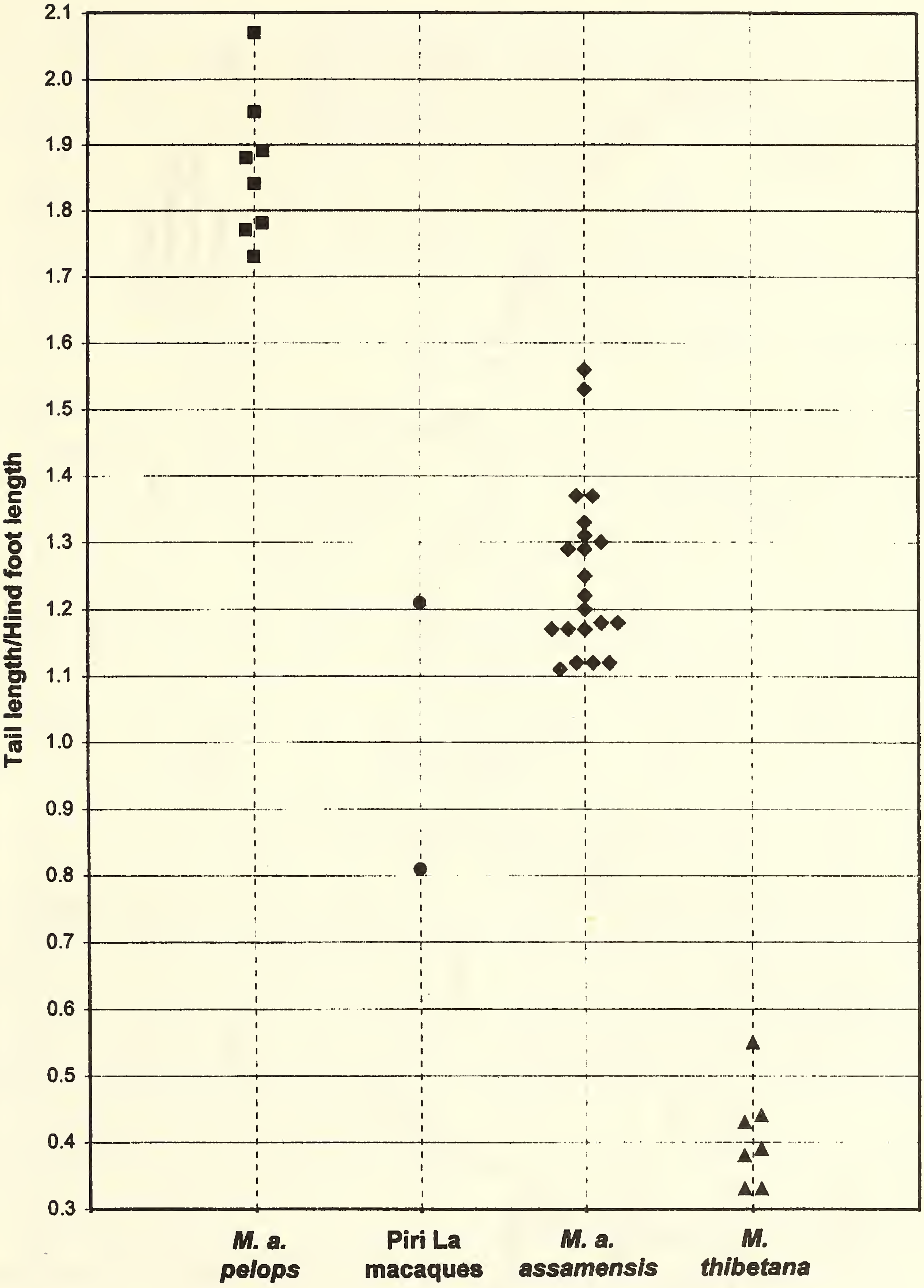
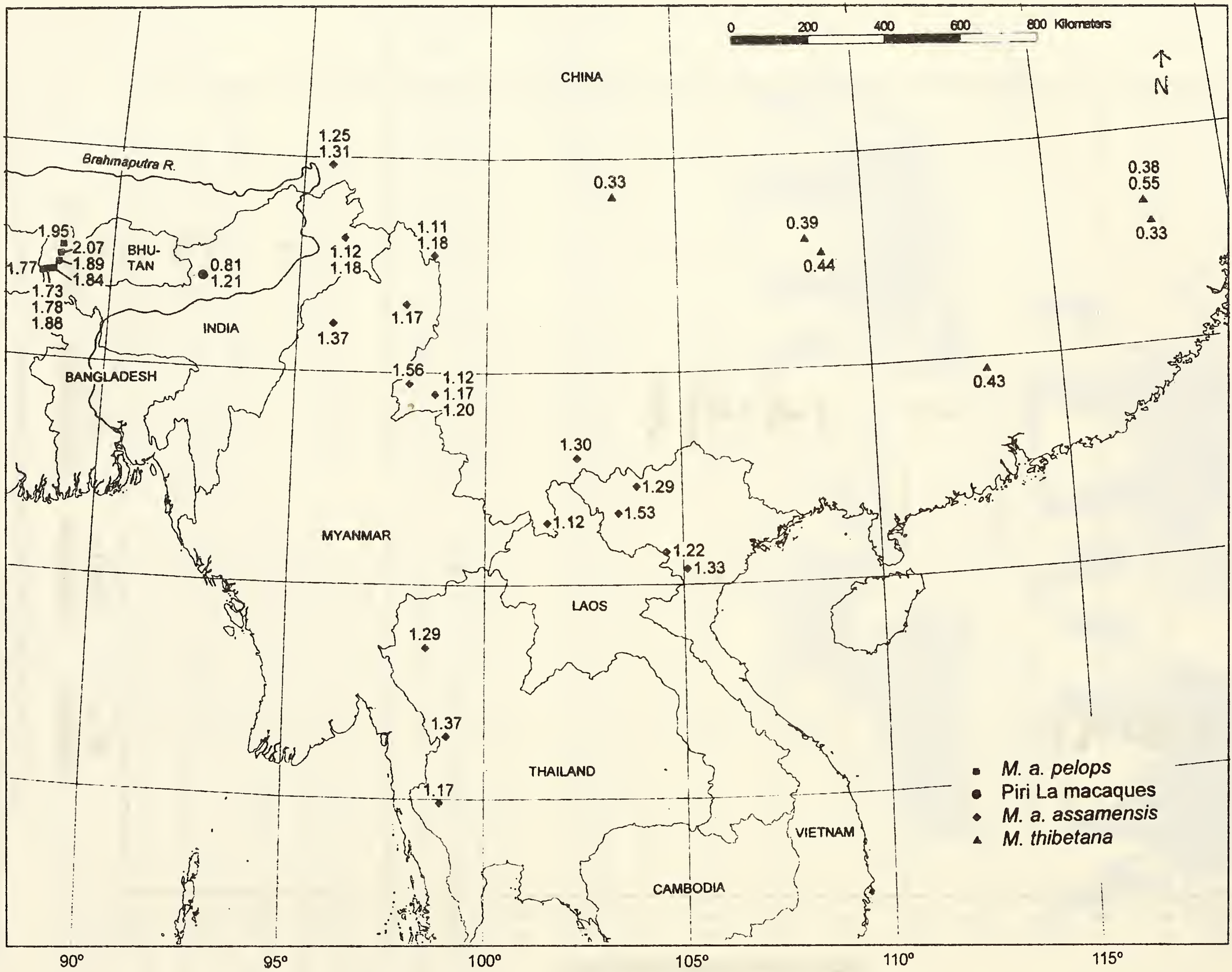


Fig. 2: Tail length/hind foot length ratios in adult male Piri La macaques compared with ratios in adult male *Macaca assamensis pelops, Macaca assamensis assamensis* and *Macaca thibetana*; for documentation see Appendix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Brahmaputra R.
BHU-TAN
INDIA
BANGLADESH
MYANMAR
LAOS
THAILAND
VIETNAM
CAMBODIA
1.25
1.31
0.33
0.38
0.55
0.33
1.95
2.07
1.89
1.84
1.77
1.73
1.78
1.88
0.81
1.21
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1.22
1.33
1.29
1.37
1.17
M. a. pelops
Piri La macaques
M. a. assamensis
M. thibetana

Fig. 3: Geographic variation in tail length/hind foot length ratio in adult male Piri La macaques, *Macaca assamensis pelops*, *Macaca assamensis assamensis* and *Macaca thibetana*; for documentation see Appendix

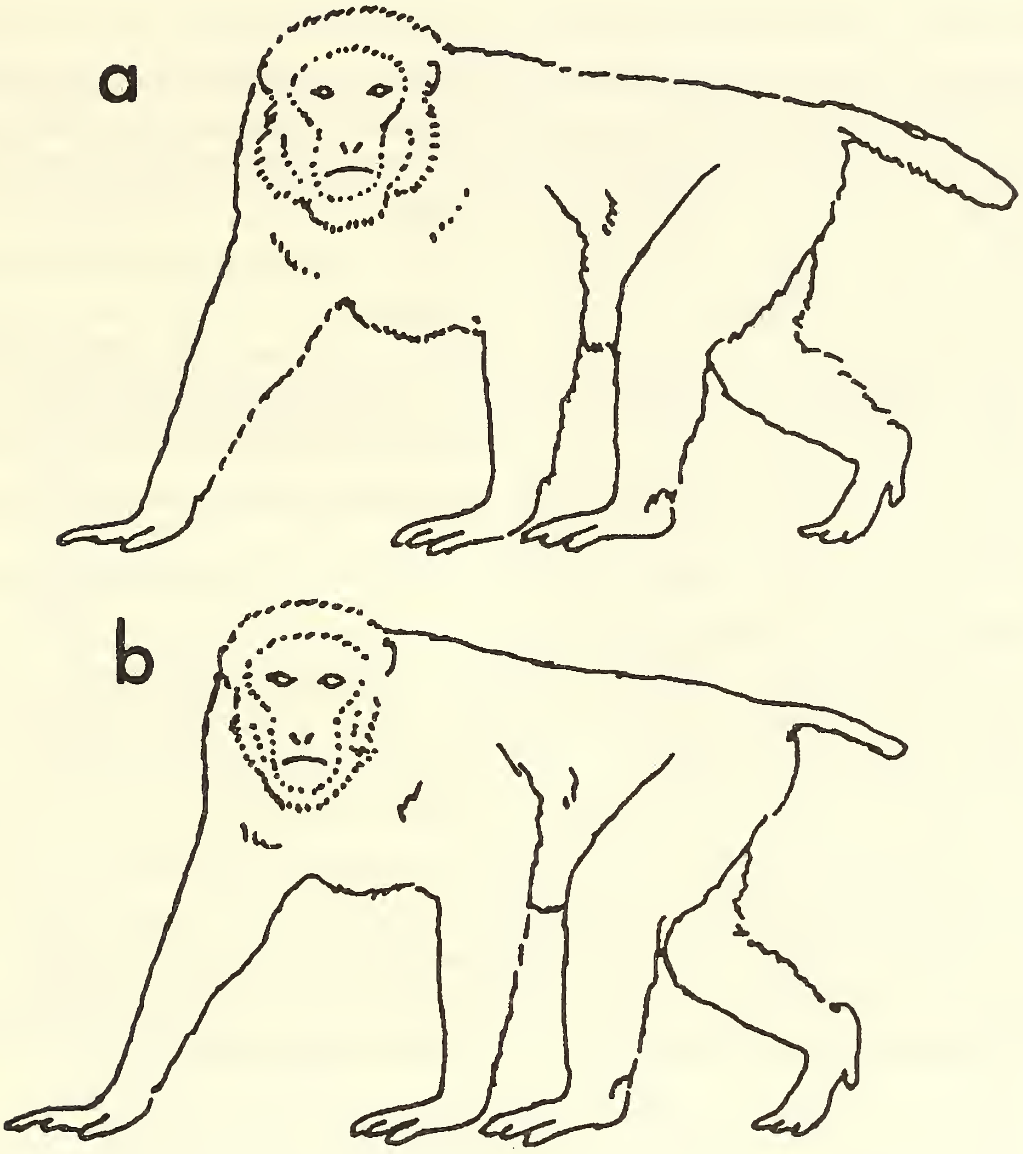

Fig. 4: Field sketches of Piri La macaques: (a) dominant adult male, (b) subordinate adult male; reproduced from Choudhury (2000, p. 13), by permission

macaques also have been reported by local inhabitants at three localities 20-60 km west and north of Piri La (Choudhury 2000, pp. 8, 15); no quantitative estimates of T/HF are available from these reports. All of these sightings of Piri La-like macaques apparently are at upper elevations, 2,000-3,100 m (Choudhury 2000, pp. 15, 20). At lower elevations, 100-2,000 m, longer-tailed *M.a. pelops* (T/HF ≈ 1.85; Fig. 2) is reportedly common in this part of western Arunachal Pradesh (Choudhury 2000, pp. 15, 20).

Choudhury (2000, pp. 4, 6, 19) further suggests that the Piri La macaques may differ from *M. assamensis* in slightly darker dorsal pelage coloration, slightly more prominent side whiskers, and in an unspecified slightly different vocalisation. Information provided concerning these subtle differences between Piri La macaques and *M. assamensis* is insufficient to permit evaluation of the postulated differences at this time; within *M. assamensis*, variation in dorsal pelage coloration and prominence of side whiskers has been reported previously (Fooden 1982, p. 6).

DISCUSSION

Judging from available information, T/HF in the Piri La adult males clearly differs from T/HF in *M.a. pelops* and *M. thibetana* adult males (Fig. 2) (cf. Choudhury 1998, p. 7; Groves 2001, p. 235). T/HF in the Piri La dominant adult male (*c.* 1.2) is near the mean value for T/HF in *M.a. assamensis*

(1.26); T/HF in the Piri La subordinate adult male (*c.* 0.8) is less than the minimum value known in *M.a. assamensis* (1.11). For the present, it seems reasonable to allocate the Piri La macaques to *M.a. assamensis*, as tentatively suggested by Choudhury (2000, p. 20). In this case, the low T/HF value of the Piri La subordinate male may be interpreted alternatively as an individual abnormality, as an expansion of the range of previously known normal variation of this character in *M.a. assamensis*, or as an artifact of the method of estimation. The uncertainty concerning T/HF in the subordinate male can be resolved, as indicated by Choudhury (2000, p. 20), by future quantitative study of T/HF at Piri La and other upper elevation localities from where Piri La-like macaques have been reported.

Assuming that the Piri La macaques are correctly allocated to the subspecies *M.a. assamensis*, the known geographic range of this subspecies is thereby extended *c.* 400 km westward along the Lesser Himalaya, west of the great bend of the Brahmaputra river (Fig. 3); a previous designation of the Brahmaputra river as the intersubspecific boundary between the ranges of *M.a.* pelops and *M.a. assamensis* was an extrapolation based on locality records then available (Fooden 1982, pp. 32, 34). Choudhury's (2000, p. 20) new information indicates that the contact zone between *M.a. pelops* (100-2,000 m) and *M.a. assamensis* (2,000-3,100 m) is located at *c.* 2,000 m along the slopes of the Lesser Himalaya, west of the Brahmaputra river, in Arunachal Pradesh and possibly also in adjacent Bhutan.

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APPENDIX

Documentation of collectors' flesh measurements of tail length and hind foot length in *Macaca assamensis* and *Macaca thibetana* adult males (cf. Figs. 2 and 3)

Coordinates	Locality, State/Province, Country	Elevation (m)	Museum[1]	Specimen no.	Tail length (mm)	Hind foot length (mm)	T/HF ratio
Macaca assamensis pelops							
27° 00' N, 88° 08' E	Batasia, West Bengal, India	900	BM(NH)	1937.3.24.8	283	160	1.77
27° 02' N, 88° 14' E	Sookia Pokhari, West Bengal, India	1,500	BM(NH)	1915.9.1.3	320	170	1.88
27° 02' N, 88° 14' E	Sookia Pokhari, West Bengal, India	1,500	BNHS	5121	300	173	1.73
27° 02' N, 88° 14' E	Sookia Pokhari, West Bengal, India	1,500	BNHS	5122	320	180	1.78
27° 03' N, 88° 25' E	Pashok, West Bengal, India	1,050	BM(NH)	1937.3.24.9	332	180	1.84
27° 14' N, 88° 33' E	Singtam, Sikkim, India	1,450	FMNH	35454	360	190	1.89
27° 25' N, 88° 35' E	Dikchu, Sikkim, India	600	FMNH	82809	345	167	2.07
27° 38' N, 88° 38' E	Chuntang, Sikkim, India	1,630	BM(NH)	1915.9.1.2	328	168	1.95
Piri La macaques[2]							
27° 07' N, 92° 26' E	Piri La, Arunachal Pradesh. India	2,000-2,700	-	dominant male	-	-	1.21
27° 07' N, 92° 26' E	Piri La, Arunachal Pradesh India	2,000-2,700	-	subordinate male	-	-	0.81
Macaca assamensis assamensis							
14° 55' N, 98° 55' E	Ban Muang Baw Ngam, Kanchanaburi, Thailand	1,100	FMNH	99622	197	169	1.17
16° 20' N, 99° 04' E	Ban Pong Nam Ron, 25 km W, Kamphaeng Phet, Thailand	750	FMNH	99631	235	172	1.37
18° 32' N, 98° 32' E	Inthanon, Doi Chiang Mai, Thailand	1,800	MCZ	37710	216	167	1.29
20° 22' N, 105° 06' E	Hoi Xuan, Thanh Hoa, Vietnam	-	BM(NH)	1932.4.19.1	230	173	1.33
20° 46' N, 104° 34' E	Chieng Ve, Son La, Vietnam	900	-[3]	Coll. 408	225	185	1.22
21° 28' N, 101° 35' E	Mengla Xian, Yunnan, China	600-700	KIZ	161	205	183	1.12
21° 42' N, 103° 22' E	Muong Moun, Lai Chau, Vietnam	350	FMNH	31765	245	160	1.53
22° 20' N, 103° 51' E	Sa Pa (earlier Chapa), Lao Cai, Vietnam	1,500	FMNH	39163	215	167	1.29
23° 00' N, 102° 20' E	Dahongshan, Yunnan, China	700-800	KIZ	Coll. 72154	240	185	1.30
24° 30' N, 98° 40' E	Zhung Shan, Yunnan, China	1,500-2,000	IZCAS	17942	204	170	1.20
24° 30' N, 98° 40' E	Zhung Shan, Yunnan, China	1,500-2,000	IZCAS	17945	205	175	1.17
24° 30'N, 98° 40' E	Zhung Shan, Yunnan, China	1,500-2,000	IZCAS	17957	190	170	1.12
24° 45' N, 98° 00' E	Yingjiang, Yunnan, China	-	IZCAS	26681	250	160	1.56
26° 08' N, 95° 57' E	Jantang-Dagung Hka, Sagaing Division, Myanmar	225	AMNH	112736	240	175	1.37
26° 36' N, 97° 52' E	Htingnan Triangle, Kachin State, Myanmar	1,050	BM(NH)	1950.385	216	184	1.17
27° 45' N, 98° 35' E	Shuanglawa, Yunnan, China	2,200	KIZ	Coll. 73429	200	180	1.11
27° 45' N, 98° 35' E	Shuanglawa, Yunnan, China	2,200	KIZ	Coll. 73430	195	165	1.18

Appendix (*contd*)

Documentation of collectors' flesh measurements of tail length and hind foot length in *Macaca assamensis* and *Macaca thibetana* adult males (cf. Figs. 2 and 3)

Coordinates	Locality, State/Province, Country	Elevation (m)	Museum[1]	Specimen no.	Tail length (mm)	Hind foot length (mm)	T/HF ratio
28° 00' N, 96° 10' E	Tebang river, Arunachal Pradesh, India	600	BM(NH)	1937.3.24.10	190	170	1.12
28° 00' N, 96° 10' E	Tebang river, Arunachal Pradesh, India	600	BM(NH)	1937.3.24.11	200	170	1.18
29° 50' N, 95° 45' E	Bomi, Xizang, China	2,750	IZCAS	Coll. 0148	200	160	1.25
29° 50' N, 95° 45' E	Bomi, Xizang, China	2,750	IZCAS	Coll. 73064	230	175	1.31
Macaca thibetana							
24° 45' N, 113° 00' E	Pingxi, Guangdong, China	800	SCIEA	Coll. 2197	80	184	0.43
27° 42' N, 108° 50' E	Jiangkou, Guizhou, China	700	KIZ	03195	80	180	0.44
27° 51' N, 117° 49' E	Chong'an Xian, Fujian, China	-	AMNH	84472	55	168	0.33
28° 01' N, 108° 24' E	Yingjiang Xian, Guizhou, China	1,250-2,350	IZCAS	17967	75	190	0.39
28° 20' N, 117° 40' E	Qianshan Xian, Jiangxi, China	1,000-1,200	IZCAS	20000	90*	165*	0.55
28° 20' N, 117° 40' E	Qianshan Xian, Jiangxi, China	1,000-1,200	IZCAS	20002	60*	160*	0.38
29° 07' N, 103°18' E	Hsiao Yang Chi, Sichuan, China	-	FMNH	38499	65	198	0.33

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[1] Key to abbreviations: AMNH = American Museum of Natural History, New York. BM(NH) = British Museum (Natural History), London. BNHS = Bombay Natural History Society, Mumbai. FMNH = Field Museum of Natural History, Chicago. IZCAS = Institute of Zoology, Chinese Academy of Sciences, Beijing. KIZ = Kunming Institute of Zoology, Kunming. MCZ = Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts. SCIEA = South China Institute of Endangered Animals, Guangzhou.

[2] Data from Choudhury (2000, pp. 13, 15); in Choudhury's drawings (p. 13), tail length and hind foot length of the dominant male are 17 mm and 14 mm, respectively, and tail length and hind foot length of the subordinate male are 11 mm and 13.5 mm, respectively.

[3] Data from Dao (1978, pp. 378, 382).

*Measurements taken on skeleton, recorded in collector's field notebook.

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STATUS, ECOLOGY AND CONSERVATION OF THE INDIAN WOLF *CANIS LUPUS PALLIPES* SYKES

(*With two text-figures and one plate*)

YADVENDRADEV JHALA[1]

Key words: Food habits, human - wolf conflict, threats, distribution

Two wolf subspecies were believed to inhabit the Indian subcontinent, the Tibetan wolf (*Canis lupus chanco*) whose range extends from the trans-Himalaya into Tibet and China, and the Indian wolf (*Canis lupus pallipes*) that ranges over much of peninsular India. Recent genetic data shows three extant wolf lineages in the Indian subcontinent. Two of these, the Himalayan and peninsular lineages, are ancient and unique to the Subcontinent, while wolves from Kashmir belong to the widespread wolf-dog clade. The Indian wolf (peninsular clade) inhabits semi-arid agro-pastoral landscapes and scrub forests. It is considered endangered, with its numbers ranging between 2,000-3,000 individuals. Undisturbed habitat patches of 5-15 sq. km that offer good cover and water are critical for successful breeding in established packs. Wolf territories range between 150 and 300 sq. km and are a function of prey and denning habitat availability. Indian wolves whelp in December-January in an underground den excavated by the alpha pair. The mean litter size is 4.8 pups. Juvenile wolves can disperse from their natal pack after the age of 8 months. The majority of wolf populations in India survive outside protected areas, and subsist primarily on livestock. In some areas, wolves have been reported to attack children. The common factors in such areas are high human population, poverty, too few or heavily guarded livestock, and poor wild prey availability. Human-wolf conflicts are of serious magnitude over much of the wolf's range in India. Wolves are persecuted by smoking pups in their dens, sometimes by shooting and recently by poisoning. Major threats to the continued survival of wolves in India are persecution by poisoning, and loss of denning habitat to intensive agriculture, development, and industry.

INTRODUCTION

Canis lupus once had the largest natural range of any land mammal, besides *Homo sapiens* (Sheldon 1992), and had successfully colonised much of the Northern hemisphere (Mech 1970). Out of the 32 odd subspecies of wolves that are currently recognised (Mech 1974), two are believed to occur in the Indian subcontinent. *Canis lupus chanco* or the Tibetan wolf is found in the trans-Himalayan region and its range extends into Tibet, China, Manchuria and Mongolia. The Indian wolf *C.l. pallipes* ranges over much of peninsular India and the same subspecies is believed to occur in Iran and Israel (Mendelssohn 1982, Shahi 1982). *C.l. pallipes* is much smaller in comparison to other subspecies of wolves, except *C.l. arabs* that is found in the Arabian peninsula.

Molecular genetic data from wolf and dog populations from around the world suggests that they belong to a closely related wolf - dog clade (Vila *et al.* 1997). Genetic analysis of mitochondrial DNA (control region and cytochrome b) of wolves from the Indian subcontinent has shown that there are three extant lineages, two of them very different from the wolf - dog clade. Wolves from peninsular India considered to be *C.l. pallipes* may have diverged from the wolf - dog clade about 500,000 years ago and are different from the *pallipes* found in the Middle East. Wolves from Himachal Pradesh to eastern Nepal (considered to be *C.l. chanco*) are basal to the other wolf clades and may have separated from them about 800,000 years ago, while wolves west of Kashmir

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belong to the widespread wolf - dog clade. Thus, the peninsular and Himalayan wolf lineages of India are very ancient and unique to the Indian subcontinent (Sharma *et al.*, in press).

Almost nothing is known about the ecology and status of the Himalayan wolf lineage. In these regions, persecution of wolves is common by pastoralists (Fox and Chundawat 1992), and it is likely that the Himalayan lineage would probably be one of the most endangered canids in the world. The account that follows is of the comparatively well-studied peninsular lineage of the Indian wolf (Plate 1, Fig. 1).

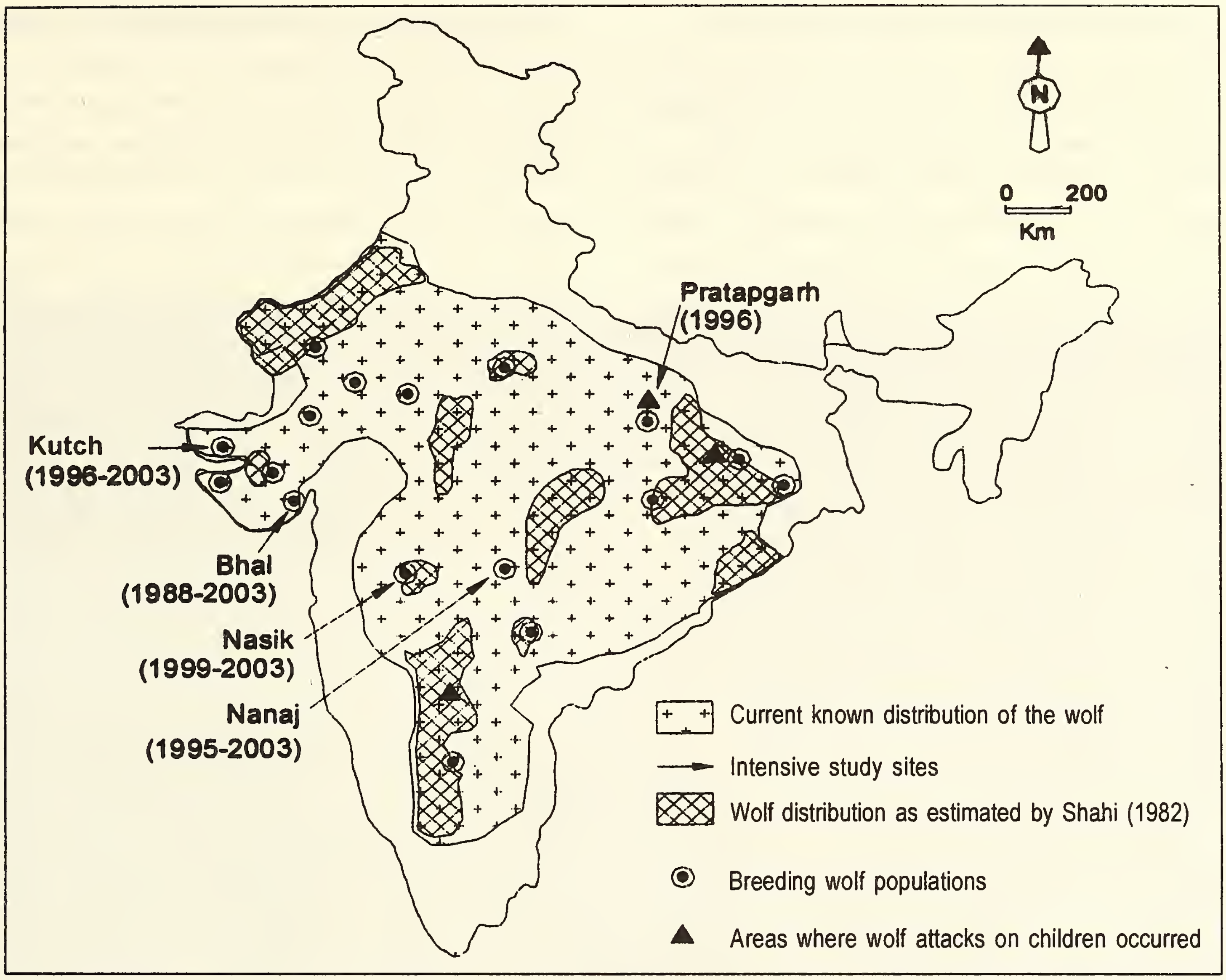
Adult male and female Indian wolves weigh between 19-25 kg and 17-22 kg respectively. Adult wolves measure between 103 and 145 cm from nose tip to tail tip, and between 57 and 72 cm at shoulder height. Coat colour is sandy brown with black hair tips. Some wolves have a more rufous tinge to their coats. Adult wolves can be distinguished from juveniles in the field by their size, behaviour, and white markings that develop above the eyes, on the chin and under the throat. Colour variation is rare among Indian wolves, black wolves being reported only from Ladakh. In much of the wolf's range in India, summer temperatures up to 47 °C are not uncommon, while winter temperatures occasionally approach 0 °C. In summer, most of the fur is shed, only sparse long hair remains on the wolf's body. This gives the wolf a scrawny, long-legged appearance.

Though the wolf is believed to have evolved as a temperate species, the Indian wolf is aptly adapted for living in semi-arid and hot environments. The small body size reduces food demands, permitting it to sustain its populations on smaller ungulates, lagomorphs and rodents; the shedding of under fur and behavioural thermoregulation permits this canid to live in hot and arid regions. The Indian wolf still needs ample drinking water, and in that sense is not truly adapted to desert living like the chinkara (*Gazella bennettii*).

STATUS, DISTRIBUTION AND HABITAT NEEDS

C.l. pallipes is considered endangered in India and features on Schedule 1 of the Indian Wildlife (Protection) Act of 1972 and of CITES (Shahi 1982). Killing or trading of *C.l. pallipes* is prohibited by law in India. Shahi (1982) in his preliminary survey estimated the wolf population in India to be about 800 individuals that were patchily distributed over peninsular India (Fig. 1). More intensive surveys in the state of Gujarat and Rajasthan have shown that wolf distribution is continuous in these states. The population of wolves in these two states was estimated to be between 450 and 620 (Jhala and Giles 1991). Analysis of recent surveys, coupled with the dispersal capability of wolves (Mech 1995) makes it likely that the wolf population within the states of Gujarat, Rajasthan, Haryana, Uttar Pradesh, Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh is continuous (Fig. 1).

The current estimated distribution of wolves covers a much larger area (Fig. 1) than was reported earlier. This does not imply range extension by the wolf, but is a result of more intensive surveys and a better understanding of wolf distribution. The wolf is still far from safe in most of its range and occurs at low densities (about 1 wolf per 100-200 sq. km, Jhala and Giles 1991). High density wolf populations (up to 5 wolves per 100 sq. km) are found to occur in some habitat pockets and preserves. Breeding packs ranging from 4 to 14 wolves have been reported from the Bhal, Dwarka, Banni, and Abdasa area in Gujarat and Kutch; Kumbhalgarh, Gudda-Bishnoi, and Pali-Barmer and Jodhpur areas in Rajasthan; Nannaj, Rehukuri, Nasik, and Phaltan areas in Maharashtra; Neoradehi in Madhya Pradesh; Rollapadu in Andhra Pradesh; Melkote and Ranibennur in Karnataka; and Mahuadaur, Hazaribag and Palamau areas in Bihar (Fig. 1). Such high-density habitats are extremely important for wolf conservation, since these pockets serve as successful breeding and recruitment areas from where wolves disperse to occupy marginal habitats.


N
0 200
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(1996-2003)
Bhal
(1988-2003)
Nasik
(1999-2003)
Nanaj
(1995-2003)
Current known distribution of the wolf
Intensive study sites
Wolf distribution as estimated by Shahi (1982)
Breeding wolf populations
Areas where wolf attacks on children occurred

Fig. 1: Distribution of the wolf *Canis lupus pallipes* in India. Locations of known breeding populations of wolves, areas where wolf studies have been conducted and areas where wolf attacks on children have been reported are shown

In the light of current information and in concurrence with Ginsburg and MacDonald (1990), a population estimate of about 2,000-3,000 wolves for the Indian peninsula seems more realistic (Jhala 2000) and may well be a conservative underestimate.

Since wolves are believed to have evolved in boreal forest systems as predators of large ungulates, it is rather surprising that the Indian wolf rarely lives in forests and prefers scrubland, grassland and semi-arid pastoral/agricultural landscapes. The Indian wolf probably evolved during the drier spells of the Pleistocene to exploit a relatively unoccupied niche as a top carnivore of the arid zones.

The eastern population of *C.l. pallipes*, found in Orissa, Bihar and parts of West Bengal, is an exception and occurs in moister forested habitats (Shahi 1982), but even here wolves are not reported where thick forests occur. Wolves occur on the periphery of protected forest areas as is seen in Kumbhalgarh and Kailadevi Sanctuaries in Rajasthan; Panna, Kanha, and Bandhavgarh National Parks in Madhya Pradesh; and Gir in Gujarat. These peripheral areas are under heavy biotic pressure from surrounding human populations and are reduced to scrub forests. It is these scrublands that wolves primarily use.

Wolves do not seem to be restricted in their movements at night and even approach very close to human dwellings and villages (Jhala 1991). In Maharashtra, radio-collared wolves were observed foraging in the Ojhar township of Nasik, at night. However, during the day, wolves are extremely selective in their habitat use, limiting themselves to habitat pockets that offer visual cover and shade, away from human disturbance. Such habitat pockets are crucial for denning and as rendezvous sites (areas where pups are kept after they leave the natal den), and could be in the form of broken terrain, rocky outcrops, rivulets, and grass or scrub patches. In Velavadar National Park and the rest of the Bhal area, wolves preferred to use moderately dense *Prosopis chilensis* patches (Jhala 1991; Jethva and Jhala, in prep.), while in Nanaj area wolves used forestry plantations (Kumar and Rahmani 1995); in Barmer and Pali districts of Rajasthan 'Aorans' (sacred groves) were crucial wolf habitats. In Ojhar-Nasik and near Jodhpur, airforce and military bases provide refugia for denning and rendezvous sites amongst a semi-urban landscape. In the Bhal area, where wolves were studied through telemetry for over eight years (Jhala 2001), core areas of wolf territories where dens and rendezvous sites were located were between 5-10 sq. km and were characterised by low human disturbance, good cover and presence of fresh drinking water (Jethva 2002; Jethva and Jhala, in prep.).

Wolves living in the western dry zone of India were considered to be nomadic, primarily following pastoralists during their annual migrations. However, telemetry studies in the Bhal and Kutch area of Gujarat, and in Ojhar in Nasik district of Maharashtra, have shown that Indian wolves are territorial like all the other subspecies of wolves. It seems likely that under certain ecological conditions territorial boundaries are more fluid. Territories of Indian wolves can be quite large, with profound seasonal use of only some areas within them, giving an appearance of "nomadism" to a casual observer. The area covered by a wolf that predated on children, in eastern Uttar Pradesh in 1996, was over 1,000 sq. km (Jhala and Sharma 1997). Food, water, and availability of habitat for denning and rendezvous sites are factors determining territory size (Fuller 1989, Jhala 1991). Wolves subsisting on wild prey in areas of high prey densities were observed to have small territories (100 sq. km), while wolves subsisting primarily by scavenging and by predation on domestic livestock had larger home ranges (250-300 sq. km) covering the grazing grounds of several villages. Territoriality acts as a spacing mechanism to limit the number of packs in an area. Prey density and prey size regulate pack size and territory size. These two factors act in synchrony to socially regulate wolf density in an area.

SOCIAL ORGANISATION

In canids, sociality increases with body size (Moehlman 1990, 1992). Wolves being the largest of the canids, have a highly developed social system. Wolf society is organised around the breeding or alpha pair, the alpha pair and its offspring living together as a pack. Thus, a pack is normally a family unit that may have been established by related or unrelated wolves. The pack stakes out and defends a resource territory from other wolf packs. Territorial defence is done by scent marking, howling and by actual strife between neighbouring packs (Mech 1970). As juvenile wolves mature, they either tend to disperse from their natal pack or stay back as helpers to their parents. Indian wolf pups may disperse as early as 7-8 months of age (Fig. 2). Dispersers wander in search of mates and available habitat to establish their own territories and packs, while helpers bide their time till they become breeders themselves by replacing and/or displacing their parent (Packard and Mech 1980). Telemetry data has shown packs to be quite tolerant to intruders. Single non-pack members were observed in close proximity to pack members and even shared kills on some occasions. Two packs were observed to intermingle without any

Jhala, Yadvendradev: *Canis lupus pallipes* PLATE 1

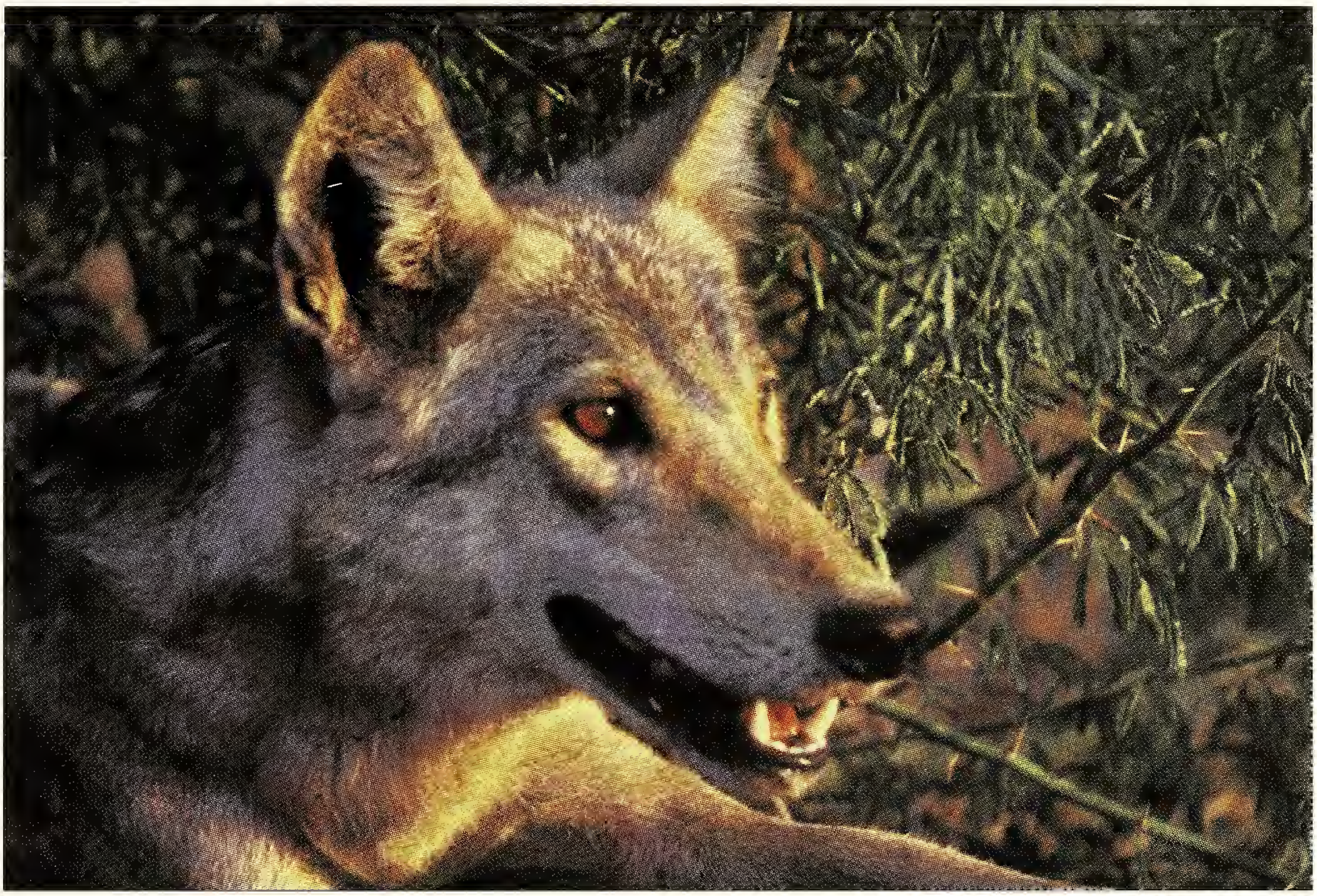

Fig. 1: The Indian wolf represents an ancient lineage of *Canis lupus* that is unique to peninsular India and parts of Pakistan. Considered to be endangered, its numbers are believed to be between 2,000 to 3,000.

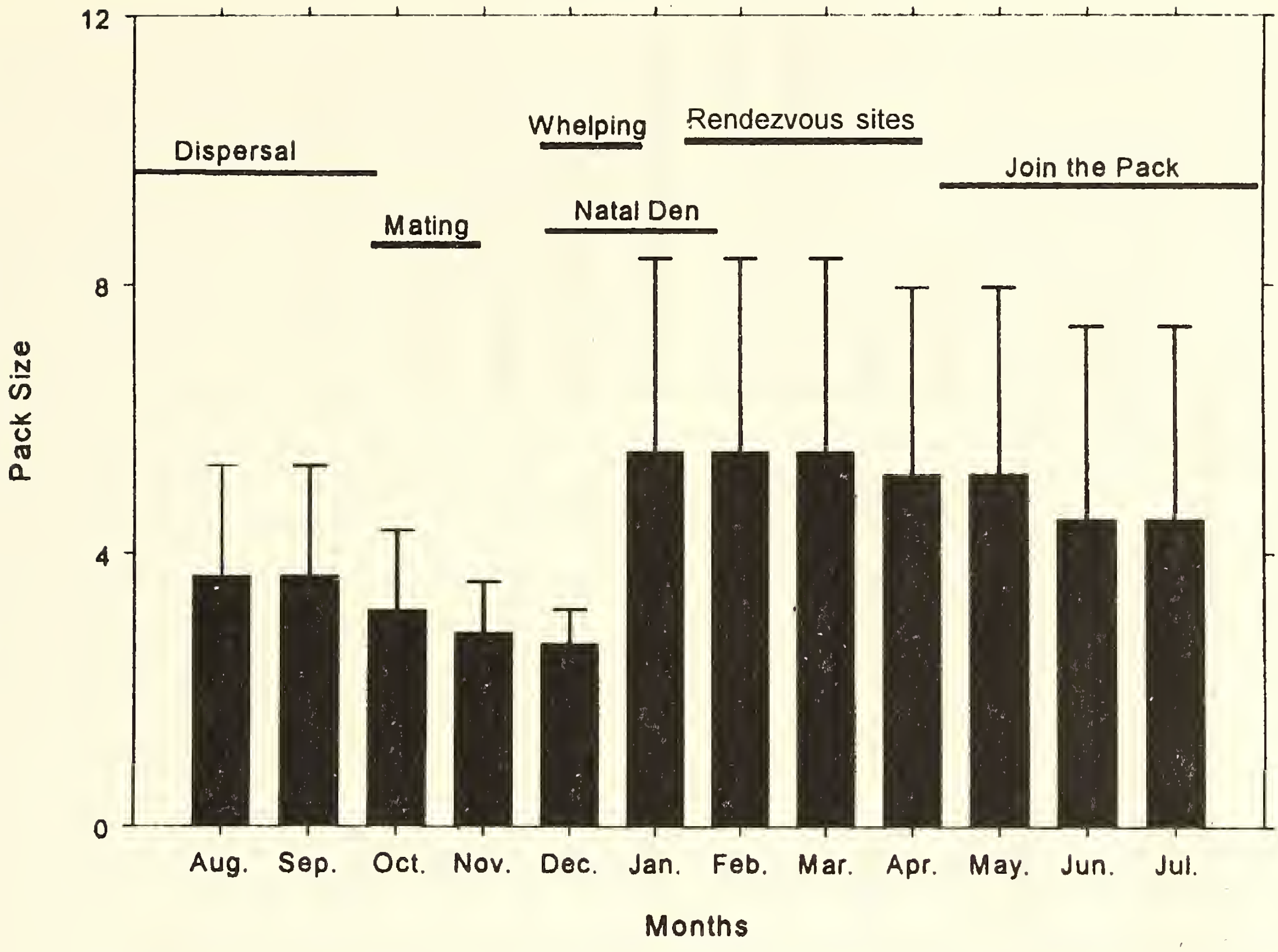

Fig. 2: Major annual events and the average monthly pack size (with standard deviation) of three wolf packs in the Bhal region of Gujarat

strife on two occasions and at one time shared the same core area for a rendezvous site. This may be an adaptation to a different set of ecological conditions, like living off clumped food resources (MacDonald 1979, Pisapio and Theberge 2000) in the form of domestic livestock carcasses, or having limited access to undisturbed habitats in a sea of human modified landscapes.

Food Habits, Predation and Consumption

Wolves are the top predators of blackbuck (*Antilope cervicapra*) and chinkara (*Gazella bennettii*), both medium-sized to small ungulates, in much of the arid and semi-arid areas of India (Jhala 1991, 1993, Sharma 1978). Food habits of wolves have been studied from seven different regions in India (Table 1). The majority of the wolf population in India occurs outside wildlife reserves, while wild ungulates are mostly limited to the reserves. Most of the studies on food habits reported here (Table 1) have been done in protected areas and, therefore, overestimate the contribution of wild prey to the wolf's diet. It would be safe to conclude that the majority of wolves in India subsist on small size livestock, primarily goats and sheep (Shahi 1982, Jhala and Giles 1991).

Reduction in body size reduces food demands and permits Indian wolves to subsist even on small prey like hare (*Lepus nigricollis*) and rodents. Besides these, wolves also eat locusts, other insects, reptiles, birds, and vegetable matter, like the pods of *Prosopis chilensis* and fruits of *Zizyphus* spp. (Sharma 1978; Jhala 1993; Jethva and Jhala, in press). In Kutch, wolves were also recorded to prey on donkeys and camel calves. Wolves of Velavadar National Park subsisted almost exclusively on wild prey, even though domestic livestock were present in

Table 1: Food habits of wolves reported as percent occurrence of prey in scats or percent of kills detected from various studies in India

Location	Method	n	Livestock				Wild prey					Source
			Sheep	Goat	Pig	Cattle	Chinkara	Blackbuck	Rodent	Hare	Others	
Bihar	Scats	130	0	30	43.1	0	0	0	3.1	7.7	16	Shahi 1982
Velavadar NP*	Scats	601	0.3	5	0	0.3	0	84.4	11.2	5.8	10.1	Jhala 1993
Nannaj*	Kills	175	13.6	43.8	0	0	0	42	0	0	0	Kumar *et al.* 1997, Kumar 1998
Rollapadu*	Kills	6	33	16	0	0	0	50	0	0	0	Manakadan and Rahmani 1997
Bhal	Scats	1,245	1	1.1	0	25.7	0	55.5	7.7	7.4	24	Jethva and Jhala, in press
Ojhar - Nasik	Scats	100	6.4	17.3	0	12.14	7	0	18.5	5.2	34	Jhala, unpubl. data
Lakhpat - Kutch	Scats	104	32.6	9.6	0	0	0	0	14.4	35.5	7.7	Jethva *et al.* 1997
Abdasa - Kutch	Scats	550	22	51	0	7.1	6.77	0	3	8.3	1.6	Jhala 2001
Overall food habits#		6	12.7	26.3	7.2	7.5	2.3	30.3	9.7	11.7	15.6	

n = sample size

*Protected areas

#Average computed with the exception of Rollapadu due to its low sample size the area (Jhala 1993). Consumption by wolves preying on blackbuck was estimated at 4.62 (SE 0.11) kg/wolf/kill. Wolves killed blackbuck at an average interval of 3.5 (SE 0.5) days (Jhala 1993). Daily consumption by wolves estimated by three independent studies was 1.33 (Jhala 1993), 1.008 (Kumar 2000), and 1.80 kg/wolf (Jethva and Jhala, in press). Jethva (2002) continuously monitored three radio-collared wolf packs in the Bhal for periods ranging from 148 to 342 hours (total 1994 hours) and quantified feeding and intake rates of these packs. Wolf predation was biased towards adult male blackbuck which contributed about 70% to the total biomass consumption of these wolf packs (Jethva and Jhala, in press). Predation on domestic livestock (cattle calves) was limited to 8%, while scavenging off cattle carcasses contributed 14% to the biomass consumed (Jethva and Jhala, in press). Wolf predation was a major limiting factor responsible for shaping the age and sex structure of the blackbuck population in the Bhal (Jhala *et al.* 2001).

Larger packs (6 to 12 wolves) were recorded in areas where wild ungulate prey was abundant, e.g. in Velavadar National Park, Gudda Bishnoi, Nannaj, Dwarka and Rollapadu. In areas where domestic livestock formed the major component of the diet, pack size ranged from 1 to 4 individuals (Jhala and Giles 1991). Large numbers are more likely to be detected by vigilant pastoralists and their dogs, and may prove to be a disadvantage while hunting domestic prey. Moreover, most large domestic livestock kills are underutilised due to human disturbance to feeding wolves and a major portion of the kill is lost to scavengers like dogs and vultures. Utilisation of kills in wilderness areas by wolves is high due to lack of human disturbance.

Wolves are capable of hunting prey much larger than themselves. This is primarily achieved by hunting in packs. Wolves when hunting in packs use different "strategies" like stalking and rushing or chasing. Most chases do not last more than 0.5 km and several of the chases are unsuccessful. Long chases of over 1 km were observed when wolves hunted blackbuck calves. Large prey is usually eviscerated and dies due to shock and blood loss. Wolves sometimes chase prey towards other pack members waiting in ambush. The technique of hunting blackbuck and chinkara by a lone wolf is by stalking, followed by a quick rush. If the prey is caught, it is normally killed by a bite on the throat or nape. The prey usually dies due to asphyxia. The majority of kills were made at night, however, during winter and monsoon, when the days were not very hot, wolves were seen hunting during daylight hours. Wolf predation is targeted towards ungulates that are old, very young or in poor condition.

BREEDING

C.l. pallipes is the only subspecies of wolf that breeds in winter. Births throughout the wolf's range seem to be well synchronised. Births in Gujarat (n=22 litters), Uttar Pradesh (n=1), and Maharashtra (n=4) occurred between December 15 and January 15. Mating occured sometime during October to November (Fig. 2), between the dominant male and female of the pack. The mating pair is locked in a copulatory tie that lasts for 20-30 minutes (Sheldon 1992). The gestation lasts for 62-63 days (Mech 1970). The breeding (alpha) female begins excavating dens about a month to 15 days prior to whelping. It takes 2-10 days to dig a complete den, and one or more dens are simultaneously excavated. The alpha male sometimes assists in the excavation but the female does most of the digging. Dens are excavated in dry river embankments. Sometimes, fox and porcupine holes are enlarged. Hollow trunks of *Salvadora oleoides*, stacks of harvested cotton stems, and rock crevices are also used (Jhala 1991, Kumar 2000, Sharma 1978). There seems to be site fidelity for denning. Four study packs in the Bhal region and two packs in Kutch excavated dens in the same area (1 km radius) for 4-7 consecutive years, even after the alpha females of three packs were replaced. A wolf den in the Gudda Bishnoi area near Jodhpur excavated in the hollow trunk of a *Salvadora* tree, showed evidence of use over several years. Wolf dens that we observed had oblong entrances with an average diameter of 48 cm (n=8, SE 14.5). The tunnels were about 3 m long with a single chamber at the end measuring about 1.1 m by 0.7 m, having an average height of 0.25 m and was at a depth of 0.6 m from the surface.

The mother confines herself to the vicinity of the den 5-7 days prior to birth. In wild wolves studied in the Bhal, Kutch, and Nasik, mean litter size was 4.8 (n=28 litters) and ranged between 4 to 6 pups. Pups are born blind, develop blurred vision by the age of 15 days and by 18-20 days, occasionally emerge from the den to play and nurse. At the age of about 30-40 days, the pups are normally moved to another den. They are moved between 4-5 rendezvous sites between the age of 40 days to their joining the pack at the age of 5-6 months.

Canid milk is quite dilute (Oftedal 1984). The lactating female needs to drink a lot of water so as to produce milk. Denning sites and rendezvous sites are so selected that fresh water is always available within a radius of 2 km. Water availability, remoteness from human disturbance, visual cover and shade, seem to be the critical parameters for selecting rendezvous and denning sites. At these rendezvous sites, pups may continue to use dens that are excavated by adult wolves and by the pups themselves up to the age of 5-6 months (till June/July). This behaviour has not been reported in other wolf subspecies and may be an adaptation in the Indian wolf to escape high ambient summer temperatures. After the pups left the natal den, they were rarely observed using a single den at rendezvous sites but were distributed in two or more dens. This behaviour was prominent in Kutch, where persecution of pups by herdsmen was severe. Rarely were all the pups killed when shepherds smoked wolf dens other than the natal den.

Nine rendezvous sites were used by the Velavadar pack over 2 breeding years. During the summer (March to early June), the rendezvous sites in and around a stream bed were intensively used. The pups would spend the hot hours of the day in cool depressions dug out in the stream bank. The depressions were 25-30 cm deep and 25-50 cm wide. These dug out depressions were also used by adult wolves for lying up. The pups were restricted to an area of 250 m radius at their first rendezvous site. Wolf tracks converged from all directions along well used trails. The area smelt strongly of wolf odour and urine. Pup and adult wolf scats accumulated in and around the area. Kill remains like bones and hides were often strewn around. The description of rendezvous sites of timber wolves in North America (Joslin 1967, Mech 1970) matches extremely well with the rendezvous sites of Indian wolves. Wolf pups were taken to feed on blackbuck kills as far as 3 km from the rendezvous site, by the age of 2.5 months in Velavadar National Park.

CONFLICT WITH HUMANS

Since the majority of the wolf populations in India live outside wildlife reserves, in human dominated landscapes, they subsist primarily on livestock. A major occupation of the people in much of the wolf's range consists of livestock rearing. Large herds of cattle, sheep, and goats graze the semi-arid landscape. Most of these livestock are malnourished and die of disease and starvation. Since humans rarely consume cattle in India, much of these carcasses are available for scavenging by dogs, vultures, jackals, hyenas, and wolves. Besides scavenging, the wolf also predates on livestock like goats, sheep, and cattle calves. Wolf predation severely affects the economy of the pastoral communities that barely manage to eke out a living from the highly overgrazed and degraded landscape of semi-arid India. The pastoral community invests significantly in measures to protect their stock from wolf predation. These measures include night vigils, maintaining guard dogs, building thorn corrals, and bringing the stock back to the village each night.

In areas with good wolf populations, average territory size would be about 150 sq. km. Considering an average stable pack size of four wolves, their density in such areas would be 2.7 wolves per 100 sq. km. Further considering that in these areas wolves would depend on small livestock (goats and sheep) to obtain about 50% of their food requirements (Table 1), a pack would predate on about 65 small livestock per year, i.e. a loss of about 43 goats/sheep per 100 sq. km. Considering an average price of Rs. 700 per small livestock, wolf predation would result in a loss of Rs. 30,000 per 100 sq. km. This would be a rough estimate of the cost of conserving wolf populations outside of protected areas. In several wolf areas in India, the State pays monetary compensation for livestock loss to wolf predation, as in Maharashtra. This practice helps negate wolf persecution by pastoralists to some extent. However, wolf predation is extremely difficult to authenticate, and paying of compensation has its difficulties in identifying false claims.

A more severe form of conflict occurs when wolves attack humans. These attacks are of two types: a) attacks by rabid wolves and b) predatory attacks on children by non-rabid wolves (Linnell *et al.* 2002). Attacks by rabid wolves are common in Maharashtra, Karnataka, Kutch, Rajasthan and Andhra Pradesh, and occur sporadically throughout the wolf's range in India. Rabid wolf attacks are rarely lethal by themselves, but could prove fatal if treatment is not provided in time. Attacks on children by wolves have been reported since British times (Blanford 1891, Lister 1917, Lydekker 1897, Pocock 1939). In recent times, such incidents have been reported from Hazaribagh in Bihar (Shahi 1982, Rajpurohit 1999), Anantpur in Andhra Pradesh, and Pavagadh in Karnataka. Jhala and Sharma (1997) confirmed attacks on children by a wolf in Jaunpur, Pratapgarh and Sultanpur districts in eastern Uttar Pradesh. Between March and October 1996, 76 children between the ages of 2 and 9 years were attacked. Of these, over 50 attacks proved fatal. A generality that emerges from Shahi (1982) and Jhala and Sharma (1997) is that in wolf range areas where there is high human density (>600 per sq. km) with poor economic status, poor child care, with little or no wild prey around, and with low or effectively guarded livestock populations, wolves could potentially attack children. Radio-telemetry data from three different areas in western India suggests that wolves come into contact with humans very often. It would be extremely easy for wolves to attack children in these areas. However, there are no authentic reports of wolf attacks on humans in these regions, in spite of their high wolf densities. Our data suggests that attacks on children are extremely rare, considering the opportunities for attacks available to wolves, and should be viewed within their special ecological and socio-economic context (Jhala 2000). However, if and when such attacks do occur, the responsible problem wolves should be controlled immediately (either eliminated or captured), so as to prevent a public backlash against the species (Mech 1995).

THREATS AND CONSERVATION

It is indeed surprising that in spite of heavy biotic pressures on the semi-arid habitats by humans and livestock populations, and severe human - wolf conflicts, the wolf continues to survive in India. The tolerant religious and cultural attitudes of people (Boitani 1992) towards all forms of life, coupled with a low density of firearms and the absence of systematic use of poison are perhaps responsible for the continued survival of wolves in most parts of the wolf's range in India. The old value system of reverence towards life forms, and attitudes that resulted in the conservation of natural resources is, however, fast changing in rural India. Goals are becoming monetary and actions exploitative. "Wastelands" and communal grazing lands are rapidly being developed for agriculture and industry. Dry farming, which is conducive to the survival of the wolf, is being rapidly replaced by irrigation and intensive farming with multiple cropping. Such intensive agriculture areas no longer support wolf populations (Jhala and Giles 1991).

Wolves were severely persecuted during the British rule in India. Bounties offered for wolves were higher than those offered for leopards (Richards 1914). This attitude persisted till the 1970s and wolves were eliminated even from the current Velavadar National Park area to reduce predation on blackbuck (Ranjitsinh 1982). Though wolves are still shot illegally in some parts of their range, hunting currently does not pose a serious threat to the survival of the species. Pastoralists and farmers smoke and dig out dens to kill wolf pups (Shahi 1982, Jhala and Giles 1991). Most wolf populations could sustain these losses due to their high fecundity rates. Recently there have been cases of poisoning of entire wolf packs in Rajasthan and Kutch. This is an alarming trend, since poison can wipe out wolves and the entire carnivore guild from an ecosystem, and needs to be dealt with severely. Poison has been the primary cause of wolf extermination throughout the world. Human attitudes and persecution of wolves is related to the amount of livestock damage caused by wolves. In Kutch, where wolves subsist primarily on livestock, attitudes are more hostile and human-caused mortality of wolves higher in comparison to the Bhal where wolves subsist on wild prey. Schemes like Maharashtra state's compensation for wolf-killed livestock help reduce persecution of wolves to some extent, but create claim-authentication difficulties.

The major threat to surviving wolf populations in India is loss of habitat resulting in depletion of natural prey densities and non-availability of appropriate denning and rendezvous sites. Wolves do breed in suboptimal habitats, but recruitment is negligible due to human-caused mortality of pups. In such areas, human - wolf conflict is heightened as wolves are forced to subsist on domestic livestock. As human values become more monetary and societies opt for quick short-term economic gain, such "wastelands" become prime targets for development of industry and intensive agriculture. Intensive agriculture, especially when irrigated by deep bore wells powered by electricity in the arid and semi-arid areas, is unsustainable in the long run. Once ground water reserves are depleted by pumping out, intensive agriculture fails. Unfortunately, this process may take decades and irreplaceable damage would have been done to endangered fauna and the ecosystem drastically altered. More permanent damage is likely to occur, to flora and fauna adapted to arid conditions, by large irrigation schemes like the Narmada Project, which will alter the land use patterns and ecosystems over several landscapes. In the rush towards short-sighted and quick economic gain, society and decision makers are not willing to consider even meagre compromises to address and incorporate conservation goals into the long-term planning process.

Recent research has identified yet another threat: canine distemper and rabies. Distemper had wiped out the entire litter of pups for 2 consecutive years (1993-94) in Velavadar National Park. Distemper is contagious and affects pups and juvenile canids, causing mortality in most of those affected. Rabies is of special concern since rabid wolves are known to attack people throughout their range (Linnell *et al.* 2002). A rabies outbreak in Kutch, in 2001-02, killed most members of my study packs. The wolves, however, showed good resilience and within a year repopulated these vacant territories. This was possible due to their dispersal ability (Mech 1995) and because wolf distribution is continuous with good source populations. Feral dogs, along with other wild canids like jackals, spread these diseases. Wolf - dog interactions are common in India. Wolves interact with feral dogs at kills and feeding sites. Wolves occasionally kill and eat dogs (Jhala 1991).

Besides distemper and rabies, dogs also transmit other diseases like parvovirus, hepatitis, and a multitude of other infections to wolves (Jhala 1991, Goyal *et al.* 1986, Mech 1970).

Indian wolves can hybridise with dogs in captivity. However, none of the wild wolves (n=45) screened by us had dog mitochondrial haplotypes, nor did dog samples from wolf territories have wolf haplotypes. This suggests that hybridisation events may be extremely rare in the wild and do not pose a threat to the wild wolf gene pool (Sharma *et al.*, in press).

A proposed national wolf conservation strategy included the following points: 1) encouraging public support and education, 2) enforcing legal protection, 3) paying compensation for wolf-killed livestock, 4) conducting surveys of wolf populations and research on the dynamics of select populations, 5) protecting breeding habitats, and 6) eradicating feral dogs from wolf conservation areas (Jhala and Giles 1991). Fig. 1 shows sites that have confirmed breeding populations of wolves. These sites are well dispersed throughout the wolf's range and many of them are in protected areas. Some of the areas that have confirmed breeding packs but no legal status should be offered some level of protection, especially during the breeding season (December to March). Further development in these areas should be discouraged. Wolf conservation is not incompatible with other land uses. Such areas could be promoted for multiple use, including controlled livestock grazing and dry farming. It is essential that remote habitat patches should be left intact in these areas for wolves to use as denning sites, rendezvous sites and resting areas (Jhala 1995). These core areas need not be of any great size, 5-15 sq. km undisturbed patches of good habitat (cover and fresh water are critical) seem to be sufficient for a pack to breed successfully (Jethva and Jhala, in prep.). Public attitudes towards the wolf in the rest of the world are rapidly improving. Wolves have in the recent past colonised areas from which humans had previously extirpated them. Such recolonisations have occurred naturally as in Scandinavia, Germany and France (Promberger and Schroder 1993), or were aided by humans as in Idaho (Fritts 2000) and Yellowstone National Park (Mech *et al.* 1995), and in the case of red wolves (*Canis rufus*) (Kelly *et al.* 2000) and Mexican wolves (*C.l. baileyi*) (Brown and Parsons 2000).

Though the wolf has probably survived in the Indian subcontinent for the past 500,000 years, its continued existence in the next 100 years is questionable. The wolf is a survivor, and does not face many of the small population problems associated with insularization that spell doom for large carnivores. With the correct attitudes and actions, we should be in a position to ensure its future.

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POPULATION STRUCTURE, COMPOSITION AND ABUNDANCE OF ELEPHANTS *ELEPHAS MAXIMUS* IN MINNERIYA NATIONAL PARK, SRI LANKA

(*With six text-figures and one plate*)

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Key words: elephant, *Elephas maximus*, Minneriya National Park, Sri Lanka

The Minneriya National Park was established mainly to enhance the long-term survival of the Asian elephant (*Elephas maximus*) in a predominantly agricultural area in Sri Lanka. The ancient reservoir, after which the Park is named, is seasonally home to large numbers of elephants because of the availability of water and the extensive areas of grassland created by fluctuations in the water level. In a preliminary study carried out from September 2000 to August 2001, a total of 974 elephants were recorded, of which 797 were classified according to age and sex. A quarter of the observations referred to solitary males. The most frequently observed grouping comprised 5-10 individuals that represent the family unit. The population structure appears to be equally divided between the adults and the other categories. The observed mean adult male:female sex ratio was 1:2.9, close to the national average of 1:3. Large groupings of elephant were observed when the drop in water level in the reservoir resulted in increase in the area of the grazing grounds. The largest group observed comprised 70 animals. There were also all-male groups, whose composition varied from 2-6. Most of the animals were observed emerging from the forest to feed on the grasslands between 1600-1700 hrs in the evening. During the rainy season, as the water level in the reservoir increased, flooding the grazing grounds, elephants moved to areas outside the Park, causing conflict with the farming community. The gradual build up of elephants in the Park leading to the observed maximum of 319 animals, translates into a crude density of 3.6 animals per sq. km, which is among the highest densities recorded in Asia. Therefore Minneriya National Park represents one of the important areas for elephant conservation in Sri Lanka. But the survival of the elephant outside the protected area can only be assured if appropriate measures are adopted to reduce the human-elephant conflict.

INTRODUCTION

Despite its small size, the island of Sri Lanka (65,610 sq. km) supports several viable populations of elephants estimated to number between 3,000 and 4,000 animals (Santiapillai and Jackson 1990). To conserve the elephant and other wildlife, Sri Lanka has set aside about 12.5% of the land area under protection. Outside the system of protected areas, a combination of high human population growth and deteriorating fertility of the land has led to increased encroachment and degradation of forests inhabited by the elephant and other wildlife. This has led to a build up of elephant numbers within the protected areas, while outside elephants are finding it increasingly difficult to move about and adjust their densities to seasonal changes in vegetation and water availability across their range. One of the more recent additions to the system of protected areas is the Minneriya National Park, opened to visitors on May 29, 1998. It is known to support high elephant numbers seasonally in response to changes in the water availability and grazing areas. However, given its central location in a predominantly agricultural area, conflict between

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man and elephant has become inevitable. No studies have so far been carried out on the ecology of the elephant in Minneriya National Park to document the seasonal build up of its numbers. It was to address these issues that a preliminary study was carried out from September 2000 to August 2001.

STUDY AREA

The 8,889 ha Minneriya-Giritale Nature Reserve was established on February 12, 1988, and was subsequently upgraded to a National Park on August 12, 1997. It is situated next to the Minneriya-Giritale Sanctuary (6,693 ha), a part of which was designated as a national biosphere reserve (809 ha). The entire Minneriya-Giritale complex is situated in an important agricultural area in the Polonnaruwa district in the North Central Province of Sri Lanka (Fig. 1). The Park is named after the ancient irrigation reservoir Minneriya, built by King Mahasena in the 3rd century AD. It has a capacity of 2,250 ha when full and a catchment area of 24,000 ha. The main source of water is from a diversion of the Amban Ganga, along the Elahara Channel (IUCN 1990).

Grasslands and a belt of dry mixed evergreen forest surround the reservoir. The vegetation in the grasslands bordering the reservoir consists of species such as *Cynodon dactylon*, *Brachiaria mutica*, *Echinochloa colonum*, *Paspalum vaginatum* and *Digitaria longiflora*, many of which are truly hydrophytic. In addition, extensive patches of grasslands composed mainly of *Imperata cylindrica* (Illuk) and *Panicum maximum* (Pohon) are also common. The forest is dense with species such as *Drypetes sepiaria*, *Chloroxylon swietenia*, *Vitex altissima*, *Manilkara hexandra*, *Limonia acidissima*, *Diospyros ovalifolia* and *Berrya cordifolia*. The fauna includes not only the endangered species, the Asian elephant *Elephas maximus* and the leopard *Panthera pardus*, but also other mammals such as spotted deer *Axis axis*, sambar *Cervus unicolor*, barking deer *Muntiacus muntjak*, wild pig *Sus scrofa* and jackal *Canis aureus*. Both sloth bear *Melursus ursinus* and wild buffalo *Bubalus bubalis* are very rare in the Park, but domestic cattle range freely in large numbers.

The Park is also renowned for its rich and diverse waterfowl, both indigenous as well as migrant. Resident birds include the painted stork (*Mycteria leucocephala*), Asian openbill-stork (*Anastomus oscitans*), white-necked stork (*Ciconia episcopus*), and the lesser adjutant-stork (*Leptoptilos javanicus*). The reservoir itself supports a variety of economically important fishes such as *Labeo dussumieri*, *Puntius sarana*, *P. dorsalis*, *P. chola*, *Cyprinus carpio*, *Mastacembelus armatus*, *Ophicephalus striatus*, etc. (IUCN 1990). The annual rainfall for the year 2000 was 1,344 mm, and the principal rainy season extended from October to January. During the dry season, which lasts from February to September, the Park receives very little rainfall, and none at all in May, June and July. The average annual temperature is 27.2 °C.

METHODS

All observations on elephants in Minneriya were made from a vehicle. We adopted the road-strip count method of Hirst (1969) to monitor the fluctuations in elephant numbers. The study area was visited at monthly intervals during which observations on elephants were made along a 14 km stretch of motorable forest track, through forest and grassland habitats. Although some animals were observed up to a maximum distance of 300 m, most of the observations fell within 200 m. As the elephants in Minneriya have been known to emerge from the forest predominantly during the evenings, all sightings of elephants were made between 1500 and 1900 hrs. At every sighting, the location of the elephants, their number, composition and activity were noted. For census purposes, the four categories recognised by Eisenberg and Lockhart (1972) — namely adult,

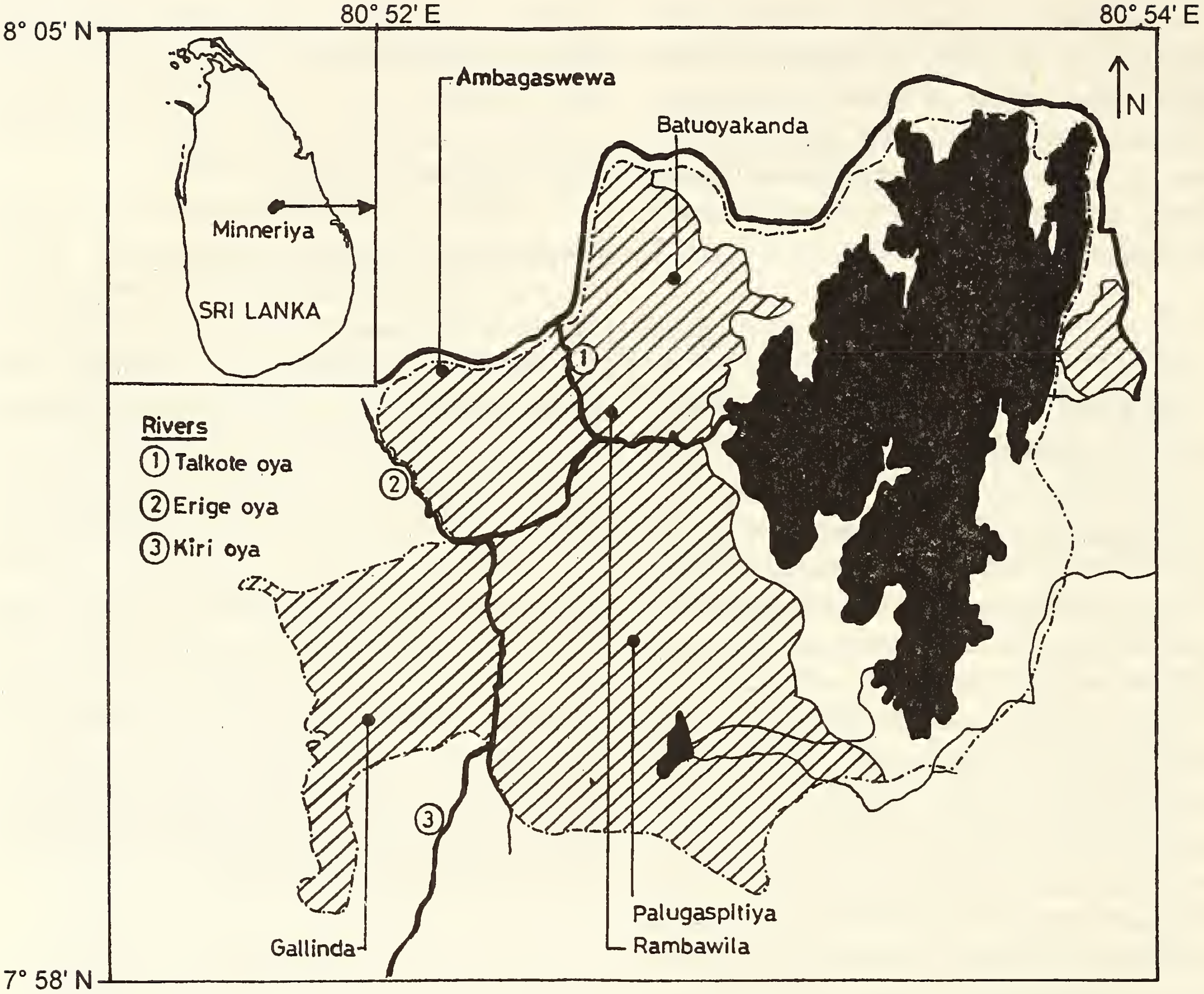


Fig. 1: Map of Minneriya National Park, Sri Lanka, showing the reservoir (shaded area), grazing grounds (open area) and forest (cross-hatched area)

subadult, juvenile and calf — were adopted. A group of elephants refers to more than two animals of any age or sex moving together in a coordinated manner, while a family unit or herd refers to an integrated unit of closely related elephants of all classes excluding adult males (Laws 1970).

Results and Discussion

Population Structure

Between September 2000 and August 2001, a total of 974 elephants were sighted from 94 observations of which 797 animals were classified according to age and sex. Nine of the observations could not be classified. Of the 94 observations on elephants, 24 (or 25.5%) represented solitary individuals (adult or subadult males), and 10 (or 10.6%) referred to all-male groups, whose size ranged from 2-6 animals. A total of 51 family units were identified (Table 1), of which 25 (or 49%) had no adult bulls, while 8 (15.7%) had only one bull, 9 (17.6%) had two bulls, 4 (7.8%) had three bulls, 3 (5.9%) had four bulls, and 2 (3.9%) had eight bulls (Fig. 2). The association of bulls with family units was temporary and was related to the presence of oestrus females (Short 1966). In an extraordinary instance, there were 8 bulls associated with just two cows. Observations by Douglas-Hamilton (1972), Croze (1974), Laws *et al.* (1975) and Poole and Moss (1981) have largely dismissed the traditional view of a single bull being an integral part of a family unit to the exclusion of

Table 1: The composition of the family units of elephants in Minneriya National Park

Family unit	Adult males	Adult females	Subadults	Juveniles	Calves	Total
1	-	11	8	5	4	28
2	-	1	1	1	-	3
3	-	2	1	1	-	4
4	-	3	3	3	1	10
5	-	2	-	-	1	3
6	2	14	21	6	6	49
7	-	3	-	2	1	6
8	-	5	2	-	4	11
9	-	3	-	1	-	4
10	-	1	1	-	1	3
11	-	2	-	2	-	4
12	-	2	-	-	2	4
13	2	17	12	10	4	45
14	1	10	6	3	4	24
15	-	1	2	-	1	4
16	2	5	1	2	-	10
17	-	4	-	1	2	7
18	-	2	1	1	2	6
19	1	6	5	2	2	16
20	-	6	4	2	3	15
21	-	10	9	3	1	23
22	1	2	4	2	1	10
23	-	5	4	2	-	11
24	-	22	7	4	3	36
25	-	11	3	3	4	21
26	2	5	2	4	-	13
27	-	1	-	2	-	3
28	2	8	3	2	2	17
29	1	8	9	2	3	23
30	2	29	18	15	6	70
31	1	12	6	6	4	29
32	2	13	4	3	3	25
33	4	2	2	2	2	12
34	-	2	2	1	-	5
35	-	3	-	1	3	7
36	1	7	1	2	2	13
37	-	1	5	1	-	7
38	-	5	4	2	1	12
39	3	1	2	-	-	6
40	8	21	10	6	4	49
41	4	2	1	3	-	10
42	1	2	-	1	1	5
43	8	1	1	-	-	10
44	3	7	3	-	1	14
45	4	7	-	4	5	20
46	3	1	-	1	-	5
47	-	1	2	-	1	4
48	2	4	4	2	1	13
49	1	1	1	1	-	4
50	3	1	2	2	-	8
51	2	1	2	-	1	6
Total	66	296	179	119	87	747

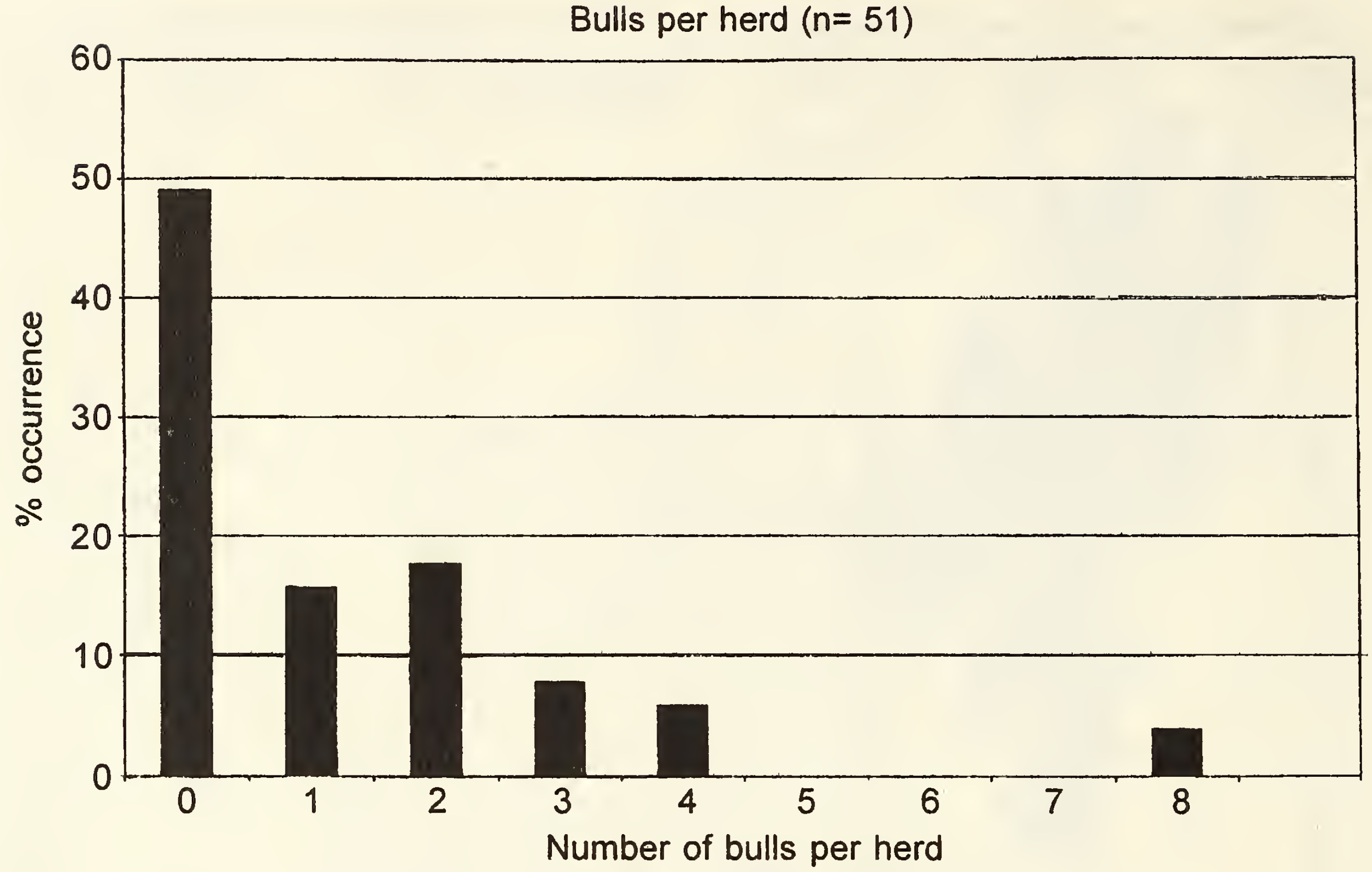


Fig. 2: The proportion of adult bulls in family units or herds observed in Minneriya National Park

other adult bulls (Rushby 1965, Sikes 1971, Poche 1974). Nevertheless, as Barnes (1982) points out, in situations where elephants form very large groups, it may pay for a bull elephant to exclude other bulls and remain with a group, given the opportunities available for mating with different females that come into oestrus. In such a situation, there is no need for the bull to move out in search of cows in heat. But in Minneriya National Park, given the small size of the groups, there would be no real advantage for a bull to be permanently associated with a group. In such a situation, the best strategy for a bull to enhance reproductive success would be to move from group to group in search of cows in oestrus. Monthly changes in structure and composition of the population of elephants are given in Table 2. As can be seen from Fig. 3, the population structure of elephants in Minneriya appears to be equally divided between adults and the other categories put together. Of the total 797 animals that were classified, 401 (or 50.3%) were adults (males, including solitary bulls, and females), while 190 (or 23.8%) were subadults and 206 (or 25.8%) were young animals (both juveniles and calves). Such an adult-dominated age structure is characteristic of several populations of elephants in Sri Lanka (Eisenberg and Lockhart 1972, McKay 1973, Nettasinghe 1973, Ishwaran 1981, Santiapillai *et al.* 1984, Katugaha *et al.* 1999). An age ratio of this type is to be expected in a species

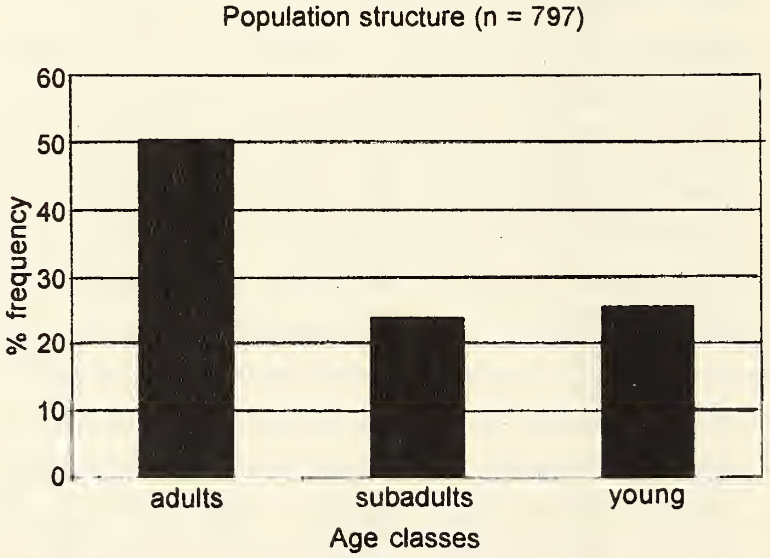


Fig. 3: The proportion of adults, subadults and young observed in the population of elephants in Minneriya National Park

Table 2: Monthly changes in population structure and composition of elephants in Minneriya National Park

Date 2000-01	Adult males	Adult females	Sub-adults	Juveniles	Calves	No. calves/ 100 cows	Total	(Unclassified)
September	10	76	58	34	28	36.8	206	(44)
October	16	80	45	28	19	23.8	188	(131)
November	9	70	40	28	18	25.7	165	-
December	0	0	0	0	0	0.0	0	-
January	4	2	2	2	2	100.0	12	-
February	0	0	0	0	0	0.0	0	-
March	3	0	0	0	0	0.0	3	-
April	1	0	0	0	0	0.0	1	(2)
May	3	0	1	0	0	0.0	4	-
June	7	5	3	2	3	60.0	20	-
July	2	8	6	3	2	25.0	21	-
August	48	57	35	22	15	26.3	177	-
Total	103	298	190	119	87		797	(177)

characterised by exceptional longevity, long gestation period and extended inter-calving intervals.

Sex-ratio

Among Asian elephants, the sex ratio does not appear to shift significantly from the expected 1:1 ratio until the subadult stage is reached (Sukumar 1989). The elephant being a polygynous, sexually dimorphic species, the adult sex ratio is unlikely to be in parity but varies considerably from place to place (McKay 1973), and is usually biased in favour of the females owing to a higher natural mortality in the males. As Sukumar (1989) points out, the sex ratio at stable age distribution will depend on the magnitude of the difference in mortality rates of male and female elephants, assuming an equal ratio at birth. Furthermore, the difference in the adult sex ratios in an area could be due to either a high mortality among males or through dispersion of the animals in space and time (McKay 1973). Thus, as Katugaha *et al.* (1999) point out, even under normal conditions, the sex ratios of progressive age classes would become increasingly female-biased in elephant populations. The observed mean adult male:female sex ratio in Minneriya, i.e. 1:2.9, is in keeping with the national average of 1:3 determined by McKay (1973), Kurt (1974) and Hendavitharana *et al.* (1994). However, within the family units, the ratio becomes slightly more biased in favour of the females 1:4.5 (Table 1), as several of them were not associated with bulls. The adult sex ratio is significantly biased in favour of the females in the months of September, October and November, during which the ratio ranged from 1:5 to 1:7.7 (Table 2). However, as Sukumar (1989) points out, since at any time, a proportion of the cows would be either pregnant or in lactation anoestrus, not all the adult females would be available for mating with the bulls. Hence, the operational adult sex ratio would not be as skewed as the one observed in the population. The observed adult sex ratios seem to indicate that the elephant population is not subject to very high mortality as a result of either poaching or conflict with man. Given the fact that females do not carry tusks and only a small proportion of the bulls (less than 7%) are tuskers in Sri Lanka, poaching for ivory is not the major cause for the disparate sex ratio. In Minneriya, there were only

4 tuskers: 2 juveniles and 2 adults. Both adults were single tusked, one being right tusked and the other left tusked, and so could easily be identified.

Group size

The most frequently observed grouping comprised 5-10 individuals that represented the family units or herds (Fig. 4). A number of family units associate temporarily to form the larger groupings seen in the Park. Family units vary in size from two (mother-calf units) to nine (three adult females with their offspring). The mean group size including solitary individuals is 10.4. If solitary individuals (i.e. bulls) are not taken into account, then the average group size increases to 13.6 (range 2-70). Of the 51 groups numbering more than three individuals, 25 (or 49%) had no adult bulls. The association of adult bulls with family units was common in the months from August to November. Large groups of elephants were observed following the build up of numbers around the Minneriya reservoir. The largest grouping consisted of 70 individuals. In addition, there were ten all male groups. These groupings appear to be temporary associations between sexually mature elephants held together by weak social bonds. They exhibit short-term cohesion. Such all male groups with rapidly shifting composition of individuals have also been recorded in Africa (Croze 1974). The maximum number of bulls seen together in Minneriya was six (range 2-6).

The composition of one of the groups (No. 43 in Table 1) that were observed in Minneriya National Park was rather strange. It had eight bulls and two cows. According to Dr. Phil Kahl (pers. comm.), who had studied the phenomenon of musth in African elephants, a possible explanation for such a strange grouping is that the older of the females was a cow in oestrus; the younger female, probably a previous calf of hers that was staying on with the mother. The 8 bulls were probably "suitors" hoping to mate with the adult

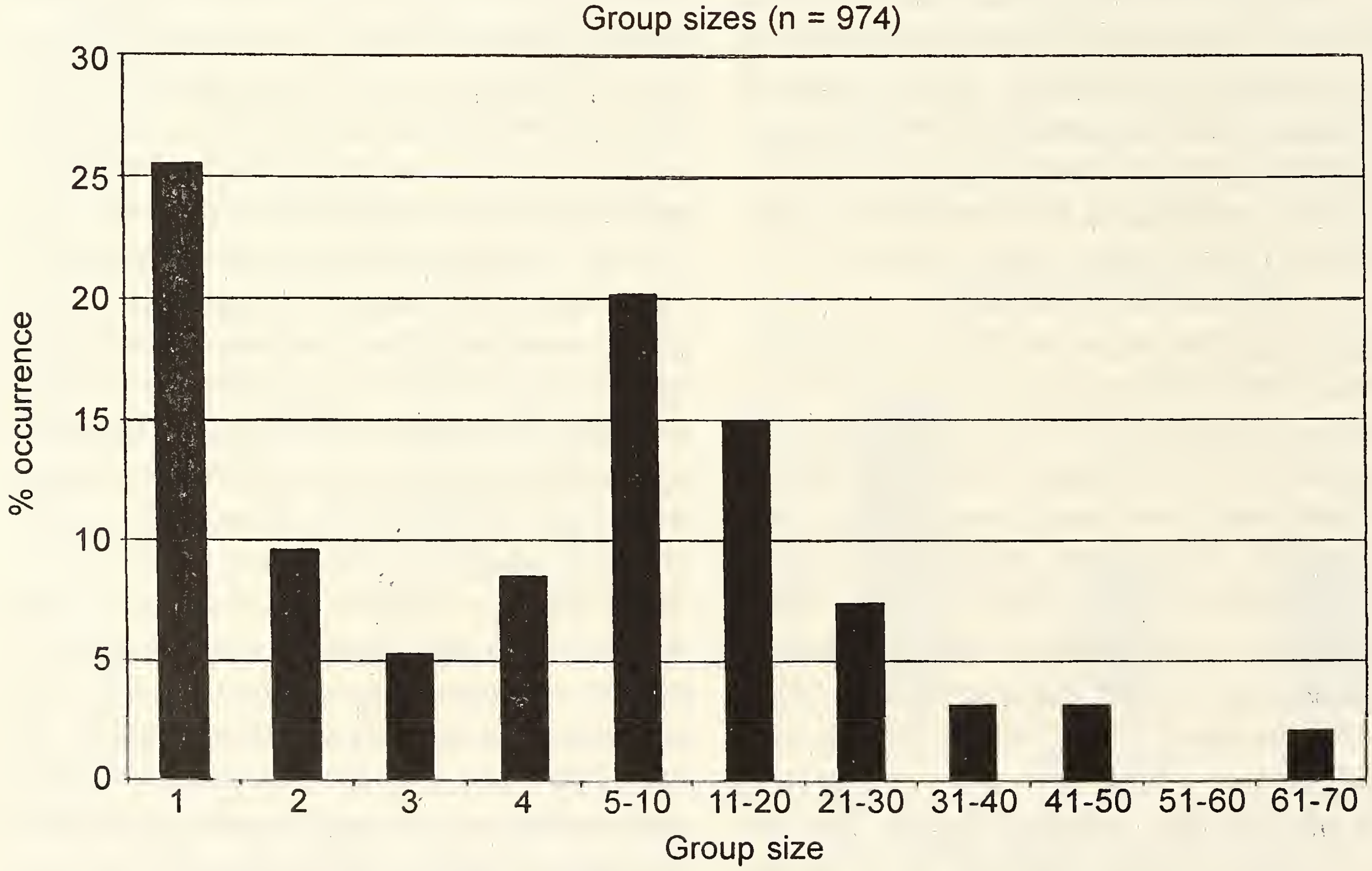


Fig. 4: Group size frequency diagram for elephants in Minneriya National Park

Santiapillai, Charles *et al.* : *Elephas maximus* PLATE 1

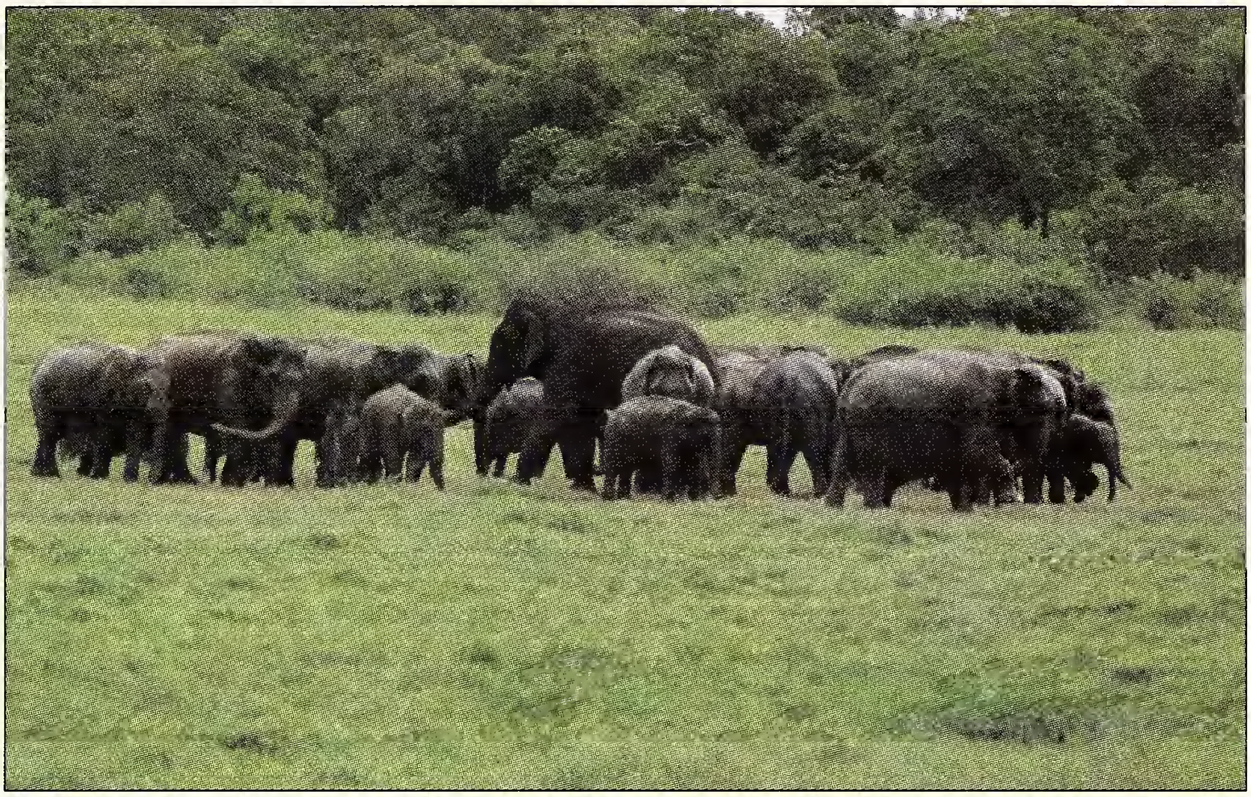
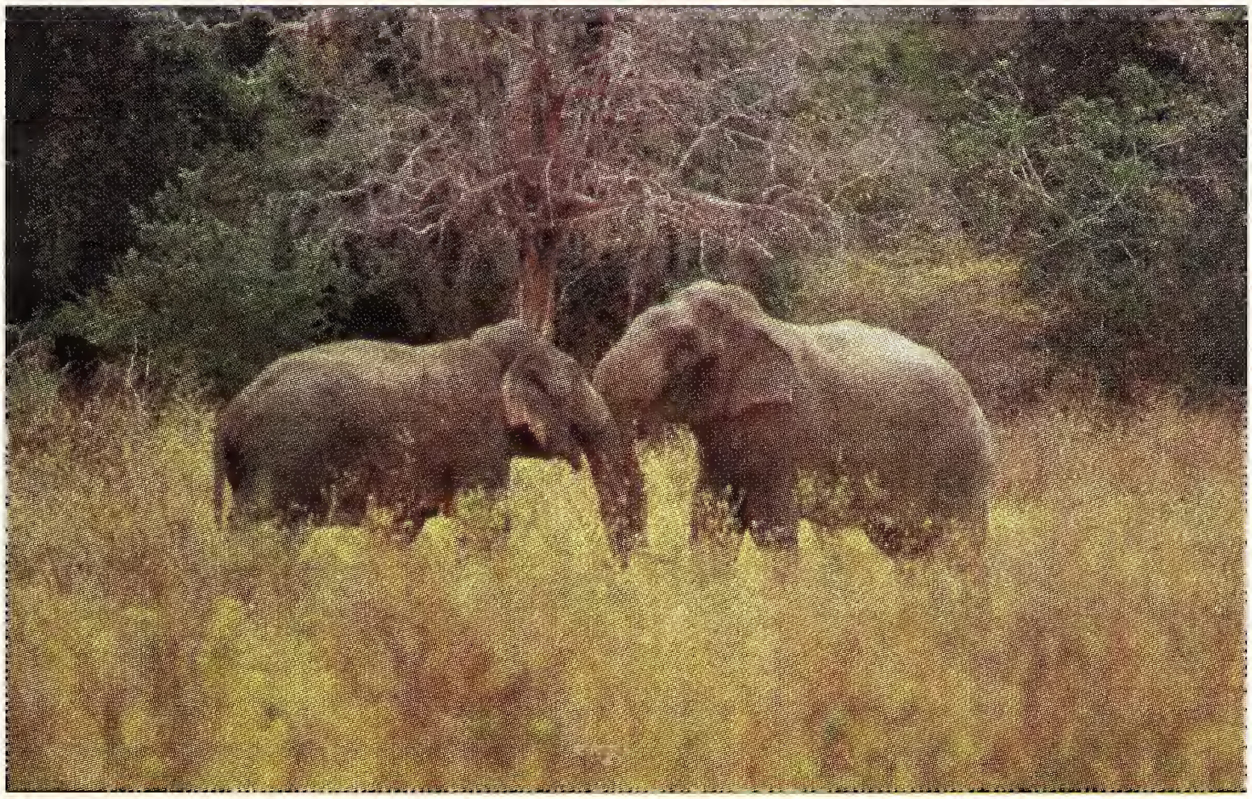


Fig. A: A herd of elephants around the biggest bull in Minneriya National Park, Sri Lanka



PICS: S. WIJEYAMOHAN

Fig. B: An encounter between two bull elephants in Minneriya National Park, Sri Lanka

female. One of them might have been a bull in musth, in which case he would most likely have been in "consort" with the oestrous female.

The mean group size of elephants varies over time and space, and some of the variation could be related to the availability of food (Leuthold 1976, Barnes 1983, Dublin 1996). In Minneriya it appears that elephants range in small groups during the dry season when food is of poor quality. Olivier (1978) correlates the decline in mean group size with a decrease in the habitat quality. It appears that smaller units of elephants are perhaps better adapted to exploit a patchily distributed resource than are larger ones (White *et al.* 1993). Of the 33 family units having 10 or more animals that were recorded during the study, 31 (or 94%) were encountered during the rainy season, and only 2 (or 6%) were seen in the dry season. As Dublin (1996) argues, the formation of larger groups allows elephants to interact, to determine dominance hierarchies and to re-establish bonds. In Minneriya, there is a gradual build up of elephant numbers from August to November as animals move in from outside when many of the smaller water holes dry up in the neighbourhood. The large Minneriya reservoir provides a year-round supply of water. Even at the peak of the dry season, grasslands around the reservoir become grazing areas for hundreds of elephants. The surrounding mixed evergreen forest provides a variety of plants on which the animals browse. As the rainy season progresses, the water level in the reservoir increases substantially, leading to the flooding of the very grasslands that support large numbers of elephants in the dry season. As the water level increases, the elephants disperse to other areas outside the Park. It is during such times that the area experiences an increase in the conflict between man and elephant. It is also the time when paddy plants have been planted extensively, and these provide rich feeding areas for the dispersing elephants. As Laws (1974) argues, the group size is a measure of the ecological health of an elephant population, given that aggregations of family units and bull groups could be the result of stressful conditions. The stress may arise through nutritional deficiency or through the loss of matriarchs following hunting (Eltringham 1977). The habitat diversity of Minneriya National Park makes it unlikely that elephants may suffer from nutritional deficiency. None of the animals that were observed in the Park were in poor condition. Besides, as the Park itself is situated within an agricultural landscape, the elephants, especially the bulls, have the opportunity to supplement their diet with highly nutritious food plants cultivated by man. Therefore, it is social factors more than nutritional deficiency and loss of matriarchs from hunting, that may determine group sizes.

Feeding activity

The distribution of elephants in Minneriya National Park appears to be aggregated, which suggests that the area is not uniformly attractive to them. Much of the elephant feeding activity was centred round the grasslands. As all the elephants were observed in the open grasslands between 1500 and 1900 hrs, grazing was the most important activity recorded. As Katugaha *et al.* (1999) point out, groups of elephants usually spend a large part of their time during the day within the forests, under shade, and so are not noticeable until they move to the grasslands in the late evenings to graze. Although elephants spend considerable time in the woodlands, trees and shrubs make up only a small proportion of their food (Buss 1961). In Sri Lanka, grasses are the most important food of elephants. But elephants alter their food habits in relation to season. Fig. 5 summarises the feeding activity pattern of the elephants observed in Minneriya. The peak of the activity was observed between 1600 and 1700 hrs, when the highest number of elephants, 388 (39.8%) were recorded. The activity fell during the next hour (1700-1800 hrs) and picked up once again from 1800-1900 hrs.

Seasonal abundance

As can be seen from Fig. 6, the number of elephants utilising Minneriya National Park increased from August, reaching a peak in October 2000 when a total of 319 animals were recorded, and declined abruptly after November. The 8 month period from December to July was characterised by a great reduction in elephants or a total lack of them. Such a build up of elephant numbers in Minneriya is the result of two related phenomena: seasonality of rainfall, and the seasonal establishment of extensive grazing grounds as a result of the release of water for cultivation. Following the monsoonal rains in November, the reservoir begins to fill with water, and as the water level increases, the floodplains become inundated, making the area unsuitable for elephants from December to April. This is the time of lowest abundance in elephants. As water is released for cultivation in May, the declining water level in the Park substantially increases the carrying capacity of the Park. Elephants move in from outside. The gradual build up leads to Minneriya supporting elephants at a crude density of 3.6 animals per sq. km. This is among the highest densities recorded in Asia. In Africa, Douglas-Hamilton (1973) recorded elephant density of 5 animals per sq. km in Lake Manyara

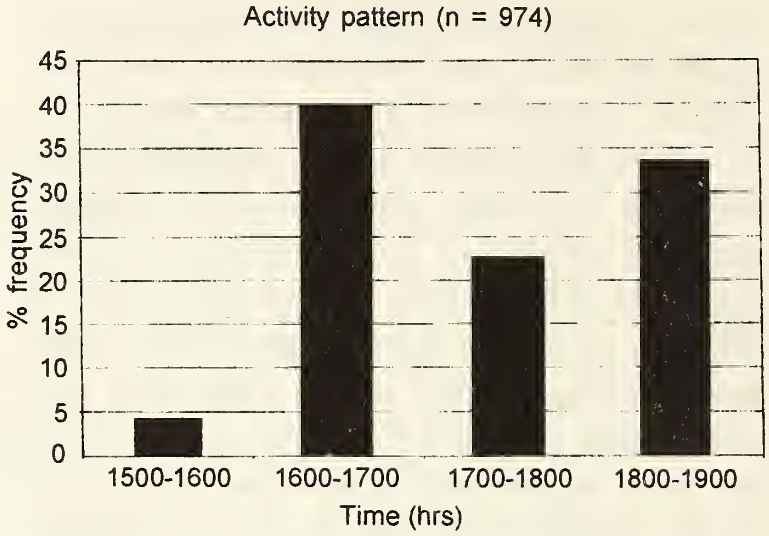


Fig. 5: Activity pattern of the elephants (both bull groups and herds) in Minneriya National Park

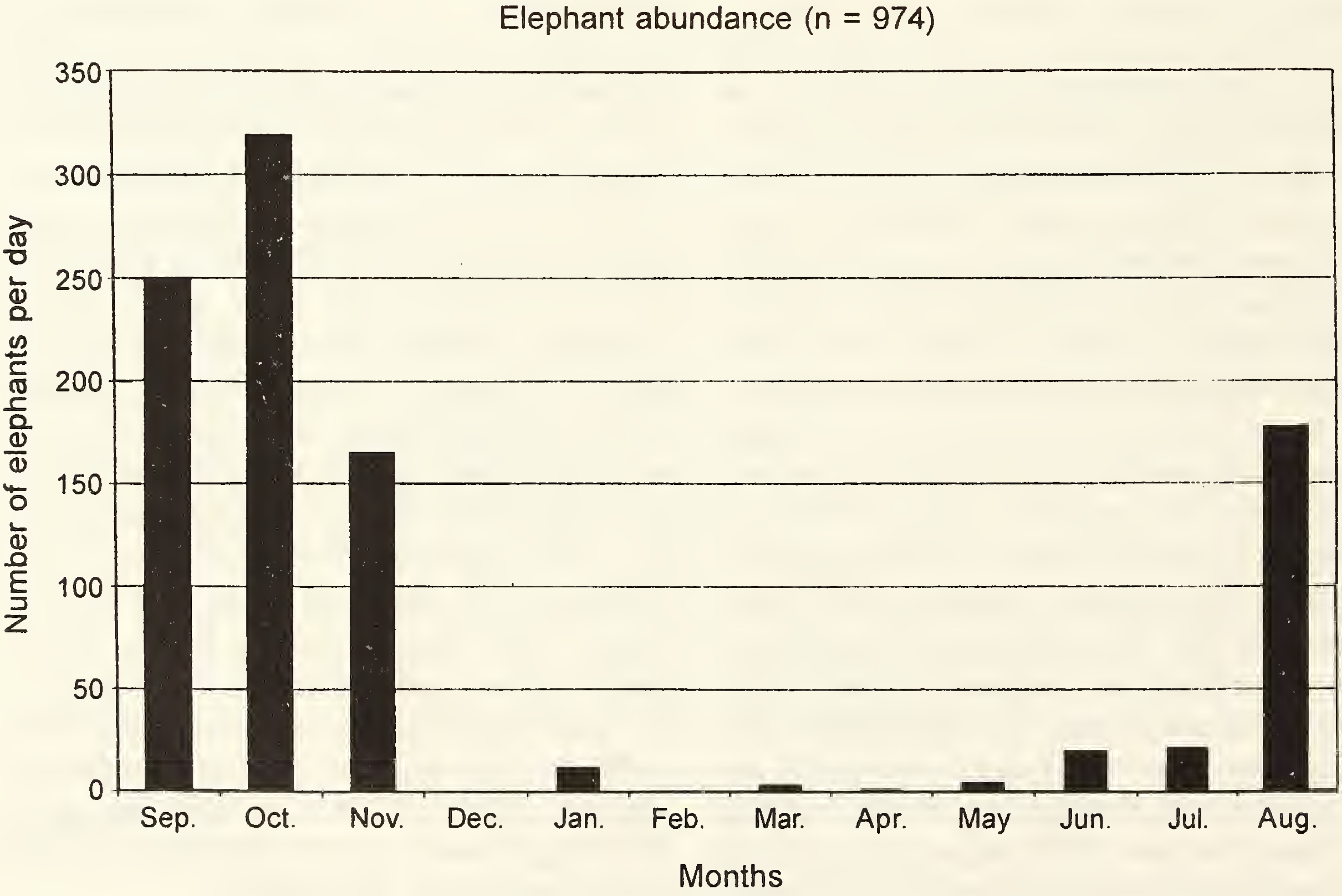


Fig. 6: Changes in elephant abundance in Minneriya National Park from September 2000 to August 2001

National Park, Tanzania. Elsewhere in Sri Lanka, the values estimated for elephant density range from 0.17 per sq. km in Gal Oya National Park in the east (McKay 1973), 0.46 per sq. km in Block I of Ruhuna National Park in the southeast (Santiapillai *et al.* 1984), and 0.12 per sq. km in Wilpattu National Park in the northwest (Eisenberg and Lockhart 1972). These density values highlight the importance of Minneriya as a conservation area for elephants in Sri Lanka. As Seidensticker (1984) points out, the water level relative to the floodplain and the slope of banks in reservoirs will determine the capacity of a catchment area to support elephants. The seasonal adjustment of water levels in Minneriya reservoir has resulted in the provision of grazing grounds for elephants, thereby making the Minneriya National Park one of the crucial conservation areas in north central Sri Lanka.

Assuming a minimum elephant population of about 300 during the peak period, and an average weight of 1,800 kg for each animal, the elephant biomass in Minneriya amounts to 540 metric tonnes and the average biomass density is 0.16 tonnes per sq. km. However, as elephants spend relatively long periods of time in very small areas, the ecological densities of elephants in grasslands can be substantially higher. Although artiodactyls such as wild pig, water buffalo, spotted deer, barking deer and sambar are present, their numbers are low, and their populations are thinly distributed across the Park. Hence the elephant remains the most important terrestrial herbivore. Its importance in Minneriya stems from its enormous size, intemperate appetite and its high mean age of survival, which as Watson and Bell (1969) point out, enable the species to make relatively massive interventions in terms of a diversion of energy flow in an ecosystem.

CONCLUSION

Elephants have been the *raison d'être* for the establishment of Minneriya National Park. Despite its small size, it is one of the important conservation areas in Sri Lanka that is able to sustain large numbers of elephants seasonally. It is an important area for the survival of a number of populations of elephants residents outside its boundaries, as it provides food, cover and water. The annual arrival and association of elephants in Minneriya during the rainy season makes the Park an *entrepot* where gene exchanges between unrelated bulls and family units are possible. Such genetic exchanges would improve the genetic fitness of the population and help keep inbreeding depression to a minimum. Furthermore, as Dublin (1996) argues, elephants may aggregate periodically in order to maintain and strengthen bonds or establish dominance hierarchies within kin groups. The fact that elephants at times were either low in number or not observed at all indicates that they, if not migratory, do undertake at least extensive movements within a large home range (Wyatt and Eltringham 1974).

The farming community in the periphery also exploits the rich grazing grounds: their herds of domestic buffalo are allowed to graze inside the Park. There are some 200 domestic cattle competing with elephants. Fortunately, there were no signs of overgrazing caused by cattle, as has been reported in Gal Oya (McKay 1973), to an extent that elephants must scarify the ground in order to feed on the short grass. Nevertheless, the number of domestic cattle needs to be controlled in order to prevent overgrazing in the future. Otherwise, heavy grazing will probably lead to a degradation of this rich grazing area and replacement of native grass by the less palatable *Imperata cylindrica.* Given the proximity of the Park to agricultural and human settlements, the long term survival of the elephant in Minneriya National Park can only be assured if management authorities ensure not only the welfare of the ecologically most dominant herbivore and its habitat, but also that of the people who compete with it for the limited resources of the land.

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THE SOUTHERN KIANG *EQUUS KIANG POLYODON*

(*With six text-figures and two plates*)

G. Neumann-Denzau and H. Denzau[1]

Key words: *Equus kiang polyodon*, skull data, morphology, distribution, threats, north Sikkim, south Tibet

The Tibetan wild ass or kiang can be divided into 3 subspecies: the Eastern kiang (*Equus kiang holdereri*), the Western kiang (*E.k. kiang*) and the Southern kiang (*E.k. polyodon*). So far, the Southern kiang was only briefly known, mainly from sparse and inconsistent material, based on Hodgson's 19th century collection in the British Museum. Now additional skulls of *polyodon*, collected in north Sikkim in 1938/39 by the expedition of E. Schaefer, have been discovered in the Zoological Museum in Berlin and for the first time examined by the authors. The data prove that the Southern kiang is indeed a separate subspecies with shorter, but relatively broader and more box-shaped head. Mounted specimens show differences in colouration and about 10-20% lower withers height than other kiangs. All available sightings of kiangs south of latitude 32° N since 1774, were brought together, analysed, locations determined and the extensive data used to draw a sound new kiang distribution map for Sikkim, Nepal and south Tibet. The distribution boundaries and populations of the Southern kiang, especially towards the west, need further investigation. Possibly there are not more than a few hundred Southern kiangs left, making it an endangered subspecies, which urgently requires more attention. Only better knowledge can help to protect the smallest kiang and its habitat adequately.

INTRODUCTION

The kiang or Tibetan wild ass has been regarded by some authors as a distinct species (*Equus kiang*), while others regard it as a subspecies of *Equus hemionus*. Even modern molecular genetic studies have not led to any agreement. While Groves and Ryder (2000) stand for the separation as a species, Schreiber (pers. comm. in 2002) suggests keeping the question open till data for its closest relative, the dziggetai (*Equus hemionus hemionus*), are available for comparison. Eisenmann (1986) is unable to discriminate between skulls belonging to dziggetai (*E.h. hemionus*) and kiang, so that she is tempted to consider the kiang as a subspecies of *Equus hemionus*. After examining a larger database (160 skulls: 35 kiangs, 29 dziggetais, 32 kulans, 37 onagers and 27 khurs), she concludes in Schreiber *et al.* (2000) that "the present osteological database supports a single-species concept for all other hemiones" (other than *hemippes*, which were omitted from discussions). One of the reasons for regarding the kiangs as subspecies of *Equus hemionus* is that the offspring of a male hybrid (kulan x kiang) and a female kulan proved to be fertile (Pohle 1983, 1986). This argument, according to clarification in Groves and Ryder (2000), is not valid.

We want to review the available data and add some new skull data as well as geographical locations regarding the poorly known southern subspecies of the kiang (*E. kiang polyodon* respective *E. hemionus polyodon*). Since the discovery and description of the Southern kiang was accompanied by several historical errors, it is necessary to explain some details of the relevant publications chronologically.

HISTORY

Early material: After a brief description of a dead specimen along with the first naming for

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Equus kiang by Moorcroft (1824) and another more detailed description of the same specimen by Moorcroft and Trebeck (1841), Hodgson (1842) postulated that a second wild member of the horse family existed in Tibet, which he believed at that time to be neither identical with the kiang of Moorcroft nor the hemione (of Pallas) but with the *Asinus*: "*Asinus equioides*, Mihi. Species wants verification, spoken of by Moorcroft and others". In fact, Moorcroft had earlier mentioned sightings of wild horses, wild asses, as well as hybrids of both, on his first visit into Tibet in 1812 (Gupta 1987). Some years later Hodgson (1847a), after obtaining some kiang specimens for examination, described these animals under the genus *Equus*, sub-genus *Asinus*, as "*Asinus polyodon mihi*," with the remarks, "very common in all parts of Tibet," and, "there is, I believe, no species of wild horse in Tibet, and only one species of wild ass, *viz.* the kiang above described ... I think the kiang may prove a new species, and I have named it *polyodon* from its singularly anomalous dentition, having 7.7 molars in the upper jaw." In a drawing of a skull and a row of upper cheek teeth, he pointed to the location of the additional tooth (today known as wolf tooth).

Hodgson (1847a) mentioned five kiangs (not clear if complete specimens or just skins), one kiang skull and later two fresh kiang specimens (provided with skulls) at his disposal. He published dimensions of a male and a female kiang, and data of a female kiang skull (all in comparison with a tanghan or Tibetan pony), but without informing the reader where exactly his kiang specimens came from (subtitle of his attached Plate 6: "*Asinus polyodon mihi*. The kiang of East Tibet"), as in those days only one kind of kiang was believed to exist all over the high altitude region.

After having received comments regarding similar dental anomalies among other equids, Hodgson (1847b) compared the teeth of three kiang skulls (all young, but no one less than 4 years old) with those of domestic horses and concluded: "That they have done so (highest authorities had uniformly given 6/6 for the Equine formula) is a fact sufficient to excuse and justify my insisting on the extra tooth commonly found in the kiang, and not, I believe, commonly found in the *Equus*."

Gray (1849) received three kiang specimens sent by Hodgson to the British Museum: "unfortunately they were so destroyed by insects during their passage from India, that it was impossible to preserve any part of them except the skull and the bones of the limbs." He described three skulls, but referred to them first (1849) as *Equus kiang*, and later (1852) as *Asinus hemionus* and *Asinus kiang*. He obviously faced a problem in placing the kiang among the equids.

In the Catalogue of the British Museum (Gray 1852, p. 273), the three kiang skulls presented by Hodgson are inadequately marked as "two skulls, lower jaw wanting." A scaled drawing of a skull (not the same as in Hodgson 1847a) is shown in Gray's Fig. 2 in Table 37.

The two special catalogues of Hodgson's collection presented to the British Museum (Gray 1846, 1863) do not mention any kiang skull, only a kiang skin (presented in 1858). However, skulls of two tanghans and another domestic equid (listed as "mule of Tibet" or "*Equus caballus* var. *domestica*") also from 1858, are mentioned. Before the second catalogue of Hodgson's collection was published by Gray in 1863, Gerrard (1862) had already published another catalogue in which he misidentified the two tanghan skulls and listed them as kiangs. This error caused confusion regarding the identity of the Southern kiang, for over a century, as even Lydekker (1916) repeated it.

Lydekker (1916) listed, in his catalogue of the ungulate mammals in the British Museum (BM), five kiang skulls presented by Hodgson to the Museum between 1848 and 1858. Three skulls from 1848 were numbered as 48.6.11.16(976a), 48.6.11.17(976b) and 48.6.11.18(976c); and two from 1858, as 58.6.24.119(976h) skull and skin, and

58.9.24.150(976g). For the 1848 skulls, Lydekker gave the locality as "probably Hundes district of Tibet", and for the 1858 animals, "upper Sikhim." Another kiang skull and skin in Lydekker's catalogue, BM79.11.21.182(976j), transferred from the Indian Museum in 1879, are also connected with Hodgson's name and with the doubtful locality "Hundes?". In 1891, a skin (and skull, the latter not mentioned by Lydekker) collected by Mandelli from Sikkim, were given the number 91.10.7.176. Lydekker described all kiangs as "*Equus kiang*."

One has to take into account (see Hunter 1896) that Hodgson collected huge amounts of zoological material from Nepal and Tibet during his time at Kathmandu (1825-1843) and later during 1845-1858 from Darjeeling (in those days part of Sikkim), and presented the collections to the British Museum. L. Mandelli was a tea planter and ornithologist in Darjeeling.

Introduction of the southern subspecies: Trumler (1959) was the first to notice a difference between some of the skulls of Hodgson's BM collection and other kiang skulls of western or eastern race, and named a new subspecies which he called *Equus kiang nepalensis*, unfortunately using 58.6.24.119 as holotype and 58.6.24.150 as paratype. Groves and Mazák (1967) investigated the skulls of the Hodgson collection from 1858 again, and concluded that Trumler's holotype and paratype belong to horses (Tibetan ponies/tanghan). When we checked the old catalogues it became evident that Gerrard (1862) and Lydekker (1916) had listed the tanghan skulls presented by Hodgson (Gray 1863) erroneously as kiang skulls, and Gerrard's location "Nepal" and Lydekker's location "Upper Sikhim" were unproven speculations. But the exact origin of Hodgson's true kiang material still remained unknown. Gerrard mentioned "Thibet" and Lydekker, "probably Hundes." Groves and Mazák (1967) believed that it came "most likely from the area of Tibet north of the Sikkhim border", while the skull 91.10.7.176 (Mandelli coll.) is doubtless from Sikkim. Groves and Mazák (1967) named the Southern kiang as *Asinus kiang polyodon* Hodgson, 1847.

Eisenmann and Shah (1996) also did not believe that certain equid skulls of Trumler's study belonged to kiangs at all. They wrote that "the skulls labelled *Kiang nepalensis trumler* in the British Museum collection (never trust a label!)" are those of *E. caballus*.

SOUTHERN KIANG MATERIAL IN VARIOUS MUSEUMS

London: 4 skulls (1♂, 3♀) and 2 skins of Hodgson's collection (dated 1848, 1858 and 1879); and 1 skin and 1 skull (♂), partly broken, collected by Mandelli in 1891.

Calcutta (=Kolkata): A kiang skull forwarded in 1838 by G.T. Lushington to the Indian Museum in Calcutta (Blyth 1863, origin: Tibet) could perhaps also belong to the southern subspecies, as the basilar length of this adult specimen is only 425 mm (our measurement), although its exact origin and history is unknown.

Blyth (1863) also mentioned 3 kiang skins presented to the museum in Calcutta by Dr. Archibald Campbell, 2 of them (mare and foal) mounted. Dr. Campbell, the Superintendent of Darjeeling, joined J.D. Hooker on one of his journeys (1848-1849) to Sikkim and south Tibet. It can only be speculated that he obtained the kiangs from the range of the southern subspecies. While searching for details, we found the following remark in Campbell's Diary (Campbell 1852), dated October 25, 1849, Lachoong: "We purchased three good skins of the kiang of Thibet to-day, a male, female, and young one, and sent them to Doctor O'Shaughnessy at Darjeeling for the Asiatic Society's Museum. The men who sold them were Thibetan hunters. People who live by hunting in Thibet are called 'Hurpo'; they are very numerous; they eat the kiang, and all other animals, use the gun, make their own powder, and are good marksmen; they cultivate and graze sheep occasionally; but live mostly by the chase." The place Lachoong (=Lachung, 27.7° N, 88.7° E) is located in Sikkim, about 30 km off the Southern kiang's distribution boundary. From these lines in Campbell's Diary we come to know that he did not hunt kiangs himself, but bought them. This, perhaps, allows us to draw the conclusion, that the kiang specimens in Hodgson's collection, some of them definitely known to be procured by Dr. Campbell as well, were also purchased at markets or from hunters in Sikkim, without knowing the exact locality.

Leiden: The catalogues of Jentink (1887, 1892) mention a skull of an adult individual *Equus hemionus* from Tibet (coll. M. Hodgson, 1853), as well as a mounted adult male *Equus asinus kiang* from Ladakh, Tibet (coll. M. Hodgson). The location Ladakh is obviously wrong. This skull, No. R1666A, has a greatest length of 501.5 mm (our measurement).

Frankfurt: At the same time as Leiden, the Senckenberg Museum obtained a kiang specimen of Hodgson's 1853 collection, from London [according to old correspondence between Horsfield and Temminck, investigated by Smeenk (pers. comm. in 2002)]. According to Kock (pers. comm. 2002), there is a skull in the Senckenberg Museum, without history, which could fit, but it was not accessible for examination due to renovations in the building.

Berlin: Ernst Schaefer went on his 1st and 2nd Tibet expeditions (1931-32 and 1934-36) as a member of the American Brooke Dolan Tibet Expeditions (Academy of Natural Science, Philadelphia). Only the 2nd expedition had collected Eastern kiangs in east and central Tibet for museum collections and also for the Zoological Museum in Berlin (ZMB).

The 3rd Tibet expedition of Ernst Schaefer went to Sikkim and south Tibet in the years 1938-39. According to museum documents we studied in Berlin (Schaefer SIII), a total of 15 kiangs were collected in northern Sikkim and given to the museum. One kiang was shot on July 28, 1938 at Gyakang, the other 14 kiangs were shot to the east of Lake Gaymtsona So between August 12-24, 1938, and on October 1, 1938. So, the origin of these specimens is well known. According to the actual filing cards, besides the 15 skulls, the museum has 7 skins of Southern kiangs (although the correspondence in Schaefer SIII mentioned 15 skins). For the identity of a mounted group of 3 kiangs see the section on Morphology.

SKULL DATA

Measurements: Out of the 15 skulls of Schaefer's collection, 14 were examined by us in ZMB, the 15th (unsexed juvenile ZMB 70291) was totally broken. All skulls were measured, but for this study we only used the data of the 7 adult specimens having six fully developed cheek teeth, i.e. 4 males with numbers ZMB 91104, 91106 (Plate 1, Fig. 1), 91107, 83377, and 3 females with numbers 91108, 91110, 83379. The juvenile skull numbers are: male 91105, 91117, female 83378, 83380, 91109, 91111, 91116.

To allow comparisons with data of other kiangs, we used here the same measurements as published by Groves and Mazák (1967) (Table 1). Groves and Mazák (1967) used, besides the 5 Southern kiang skulls of the British Museum, two skulls (ZMB 91106 and 91110) from Berlin (Groves, pers. comm. in 2002). This means that two skulls of Schaefer's collection were available in ZMB at that time. The others remained — for reasons unknown — undetected so far.

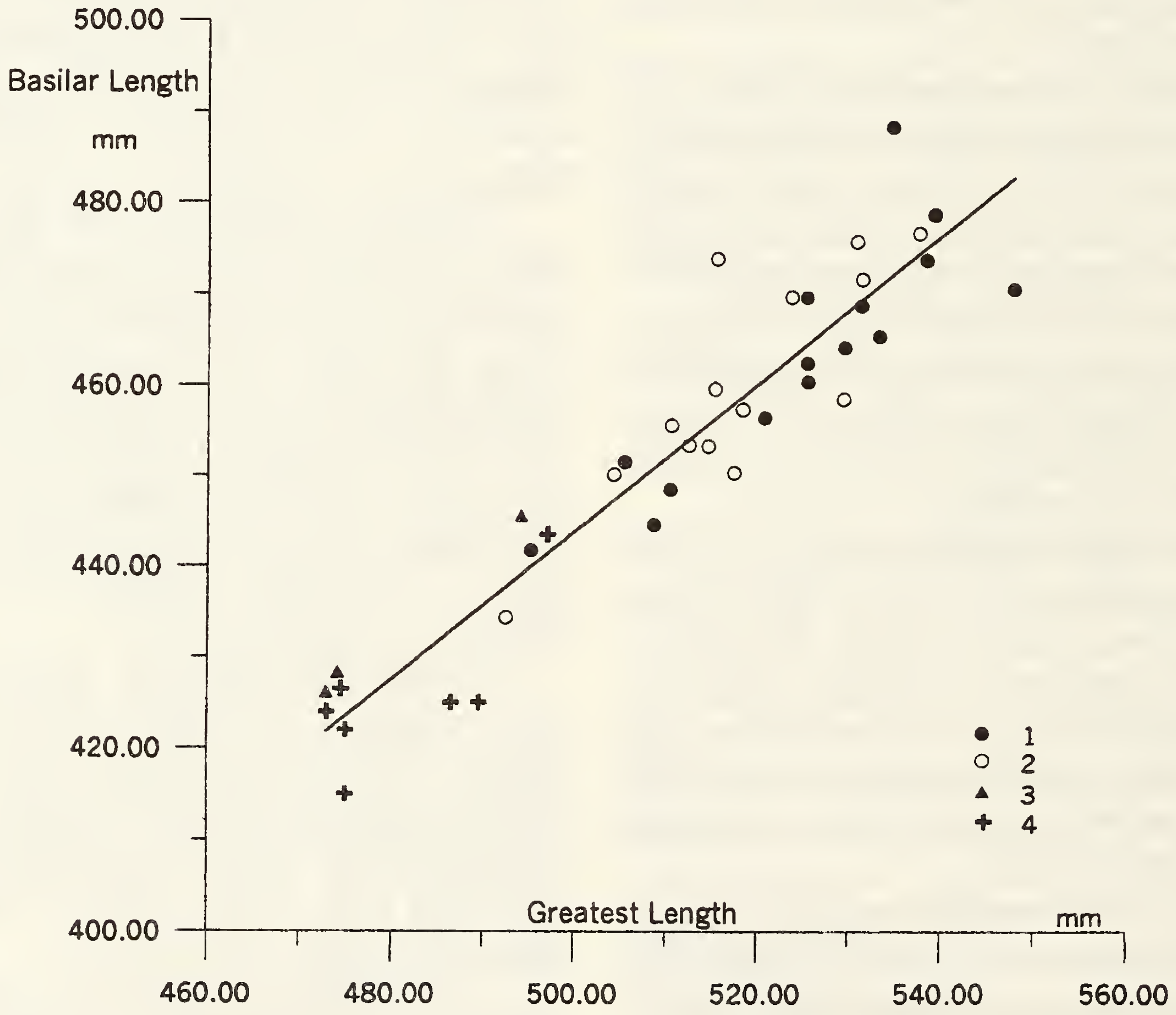
Results of comparisons: Single values for the 3 subspecies of kiangs are only found as graphics in Groves and Mazák (1967) without distinction between males and females. To enable a comparison between our measurements and the other kiang data, we digitised their figures and added them to our Figs 1, 2 and 3.

A comparison of length measurements of all kiangs (Fig. 1, basilar length vs greatest length) shows that *polyodon* is significantly smaller than the other kiang subspecies. While Groves and Mazák (1967, p. 352) observed a "long basal length compared to the greatest length" for 3 specimens

Table 1: Skull measurements

No.*	Measurement	Specification
1	Greatest length	Prosthion to inion
2	Basilar length	Prosthion to basion
3	Palatal length	Prosthion to hind border of palate, in midline
4	Diastema length	Hind border of I^3 alveolus to front border of P^2 alveolus
5	Toothrow length	Front border of P^2 alveolus to hind border of M^3 alveolus
6	Diastema breadth	Breadth of palatal surface in diastema region
7	Incisor breadth	Breadth of premaxillae across incisor alveoli
8	Palatal breadth	Breadth of palate between inner borders of P^3 alveoli
9	Orbital breadth	Breadth of skull across posterior margins of orbits
10	Occipital breadth	Breadth of occipital crest
11	Opisthion to inion	Distance from opisthion to inion
12	Nasal length	Length of the internasal suture

*Numbers refer to numbers on the abscissa in Fig. 4 and Fig. 5.



1=*holdereri*, 2=*kiang*, 3=*polyodon*; 4=*polyodon* (Schaefer's collection)

Fig. 1: Skull measurements of 3 subspecies of kiangs: basilar length vs greatest length, based on Fig. 9 in Groves and Mazák (1967), with additional skull data of the Southern kiang and with linear regression line for all data (n=39)

Neumann-Denzau, G. and H. Denzau: Southern kiang *Equus kiang polyodon* PLATE 1

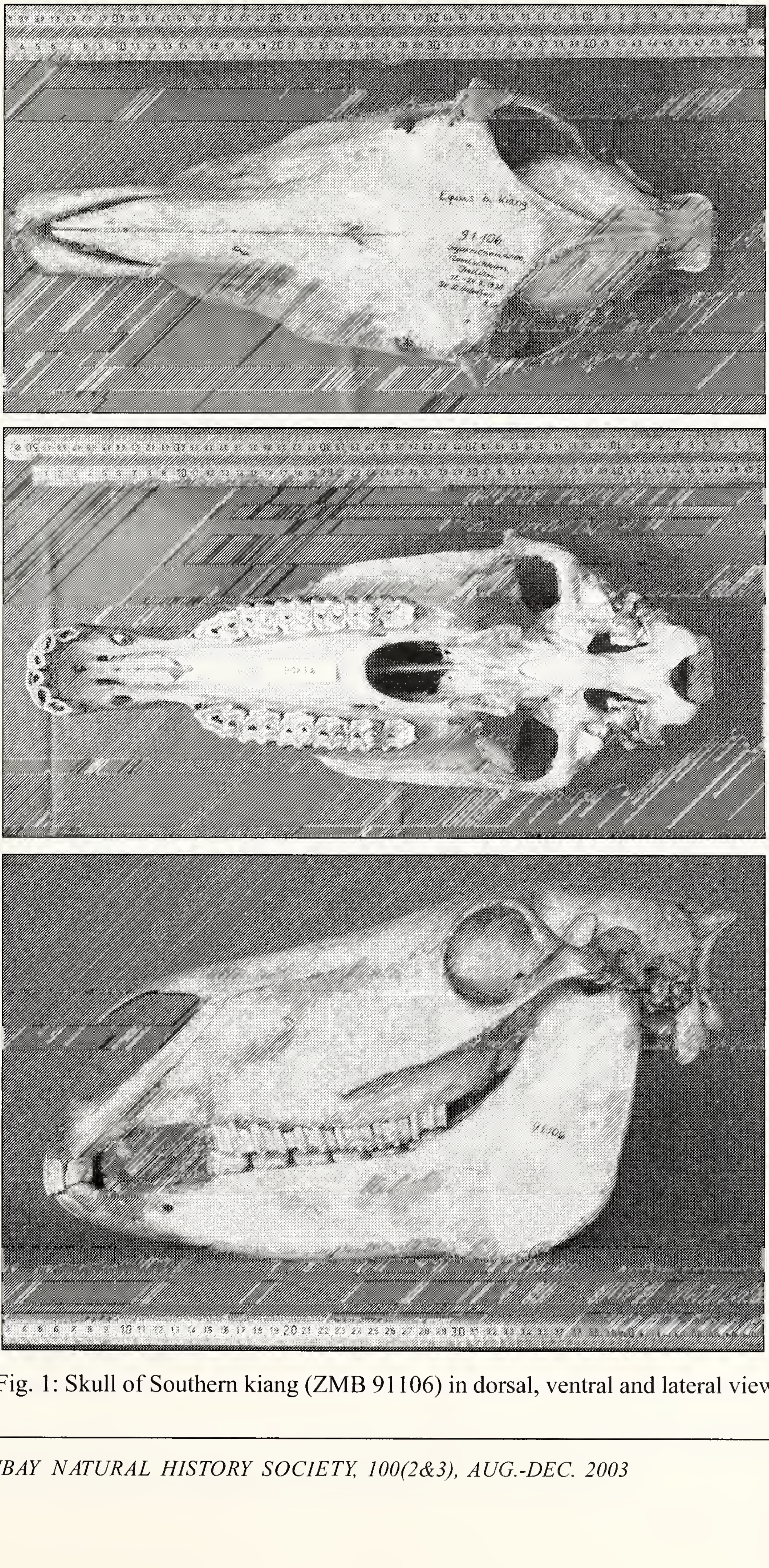

Equus k. kiang
91106
91106

Fig. 1: Skull of Southern kiang (ZMB 91106) in dorsal, ventral and lateral view

Neumann-Denzau, G. and H. Denzau: Southern kiang *Equus kiang polyodon* PLATE 2

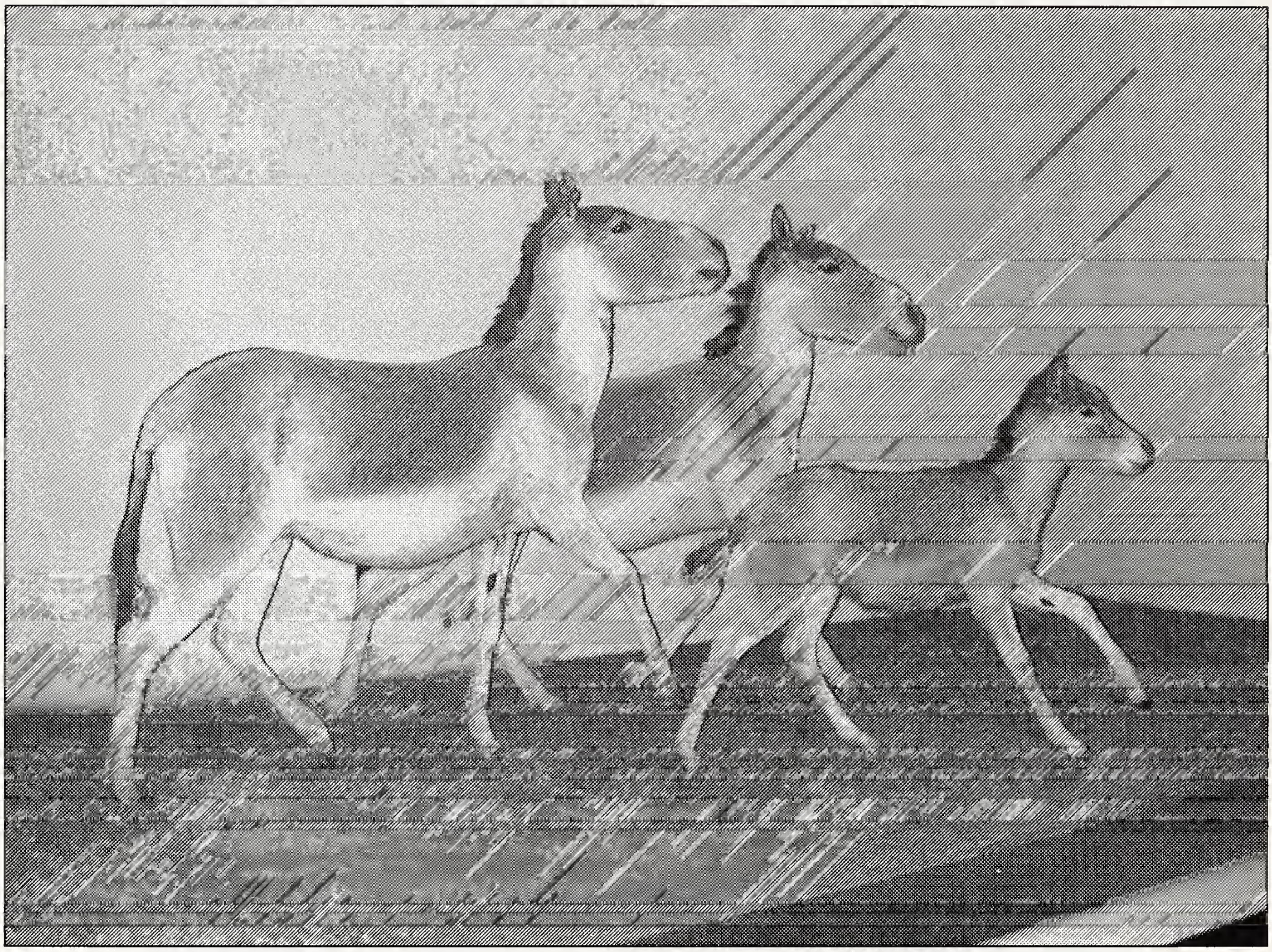


Fig. 1: Mounted group of Southern kiangs (Schaefer's collection) in the Natural History Museum, Berlin

of *polyodon*, the 7 specimens of the Schaefer collection fit in well with the linear trend of all subspecies. Therefore, taking the now enlarged sample size of *polyodon* into statistical consideration, their statement cannot be corroborated.

However, on looking at the relation of skull breadth to length, it can be noticed that the measures of *polyodon* are not the smallest among the kiangs. The incisor breadth compared to the palatal length (Fig. 2) is, for example, quite large, indicating a broad muzzle.

On the other hand, the graph of 'nasal breadth vs nasal length' (Fig. 3) demonstrates that Western kiangs and Southern kiangs show no significant difference. The nasal breadth was taken at the point above the infraorbital foramen.

Table 2 contains the mean values of skull data of Southern kiangs in Schaefer's collection, in addition to skull measurements as published earlier by Groves and Mazák (1967). Despite the uncertainties regarding the origin of some of their skulls, the *polyodon* mean values of Groves and Mazák fit in well with the Schaefer data.

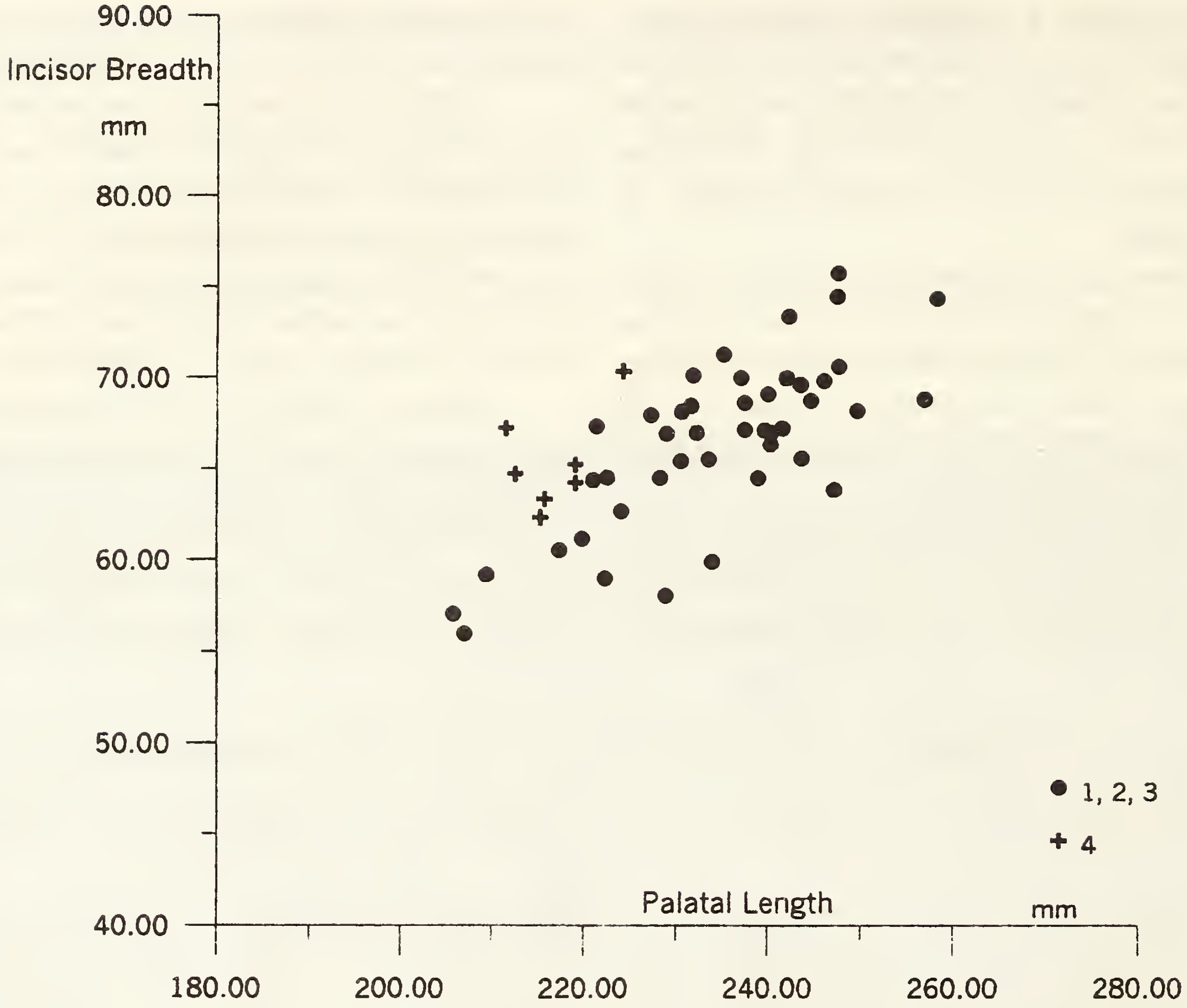
When comparing the differences of the skull mean values between the kiang subspecies and the kulan (*Equus hemionus kulan*), it becomes evident that the length measurements (1-5) of *polyodon* are almost equal to those of the kulan (Fig. 4). The breadth measurements 7 and 10 are

Table 2: Mean values of skull measurements of 3 kiang subspecies (in mm ±SE)

No.	Measurement	n	*holdereri* *	n	*kiang* *	n	*polyodon* *	n	*polyodon* **
Males:									
1	Greatest length	7	527.7 ±12.6	10	518.4 ±12.0	2	473.0	4	477.4 ±6.2
2	Basilar length	7	463.1 ±9.4	10	461.2 ±12.9	2	426.0	4	421.4 ±4.5
3	Palatal length	7	238.4 ±6.6	10	235.0 ±10.7	2	226.5	4	215.4 ±3.1
4	Diastema length	7	87.0 ±6.7	10	81.5 ±6.3	2	75.0	4	75.1 ±6.2
5	Toothrow length	5	168.2 ±3.3	5	159.8 ±4.0	3	156.0 ±2.6	4	150.5 ±4.6
6	Diastema breadth	7	47.3 ±3.5	10	45.9 ±2.0	2	40.0	4	44.8 ±3.8
7	Incisor breadth	7	69.1 ±4.0	10	69.8 ±3.0	2	66.0	4	64.5 ±2.2
8	Palatal breadth	7	60.6 ±4.3	10	55.4 ±6.5	3	45.7 ±2.1	4	51.8 ±3.8
9	Orbital breadth	7	207.4 ±6.8	10	211.8 ±8.3	3	201.3 ±5.1	4	206.2 ±4.8
10	Occipital breadth	7	58.9 ±2.9	10	55.2 ±4.0	2	53.5	4	55.2 ±2.7
11	Opisthion to inion	7	61.3 ±2.5	10	60.3 ±2.9	2	55.0	4	56.2 ±3.1
12	Nasal length	6	220.2 ±6.1	9	203.2 ±6.8	3	195.0 ±3.5	4	195.2 ±4.2
Females:									
1	Greatest length	7	519.3 ±14.7	5	514.2 ±9.0	3	481.0 ±11.3	3	487.0 ±11.5
2	Basilar length	7	458.1 ±11.5	5	456.4 ±7.5	2	436.5	3	431.7 ±10.3
3	Palatal length	7	240.7 ±8.3	5	238.3 ±3.2	3	226.0 ±4.7	3	218.6 ±5.9
4	Diastema length	7	86.0 ±6.5	5	88.6 ±6.5	3	79.0 ±2.2	3	76.9 ±4.3
5	Toothrow length	7	165.0 ±4.3	2	154.0	4	156.0 ±3.7	3	154.8 ±5.7
6	Diastema breadth	7	46.2 ±3.4	5	44.0 ±2.2	3	45.0 ±3.9	3	46.1 ±2.4
7	Incisor breadth	7	68.7 ±1.4	5	64.0 ±3.6	3	66.3 ±3.3	3	66.4 ±3.4
8	Palatal breadth	7	59.7 ±3.6	5	54.8 ±3.1	4	47.0 ±3.6	3	51.2 ±1.8
9	Orbital breadth	7	210.6 ±6.7	5	205.6 ±6.4	4	207.3 ±3.2	3	203.2 ±9.2
10	Occipital breadth	7	57.1 ±3.9	5	57.7 ±2.2	3	52.7 ±3.8	3	55.9 ±3.1
11	Opisthion to inion	7	63.4 ±2.4	5	62.3 ±4.1	2	59.5	3	56.9 ±4.8
12	Nasal length	3	223.0 ±11.0	3	203.6 ±4.0	3	198.3 ±5.3	2	189.7

* Data of Groves and Mazák 1967, p. 329.

** Schaefer's collection, ZMB.



1,2,3=unspecified kiang subspecies; 4=*polyodon* (Schaefer's collection)

Fig. 2: Skull measurements of kiangs: incisor breadth vs palatal length, based on Fig. 7 in Groves and Mazák (1967), with additional skull data of the Southern kiang

about 10% larger, the measurements 8 and 11 on the other hand almost 10% smaller. Skull measurements of the Eastern kiang (*Equus kiang holdereri*) are always the largest.

Compared to the nominate form (*Equus kiang kiang*), the skull of the Southern kiang proves 8-10% smaller in length measurements 1-4 (Fig. 5). Measurements 8, 11 and 12 reveal certain differences among the 3 kiang subspecies. It is obvious that in the Southern kiang, not only the incisor breadth (7), but also the diastema breadth (6), the orbital breadth (9) and the occipital breadth (10) are proportionally larger than in other kiang subspecies. Due to these parameters we can characterise the Southern kiang as more broad-headed. This fact is the opposite of Trumler's erroneous statement, terming the heads of the Southern kiangs as rather horse-like, "slim and long."

Trumler (1959), after examining the skulls of kiangs, distinguished 3 different subspecies with the help of the 'Stirnbreitenindex'. His index is identical with the 'cephalic index' of Osborn (1912): frontal width at posterior borders of orbits, multiplied by 100, divided by basilar length. He found a cephalic index of 44-46 for the Eastern kiang, 46-49 for the Western kiang and only 43 for the Southern kiang. We determined a cephalic index of 48.1 ±1.5 for the 7 *polyodon* skulls of Schaefer's collection. The low value of Trumler for the Southern kiang is due to the erroneous use of some tanghan skulls.

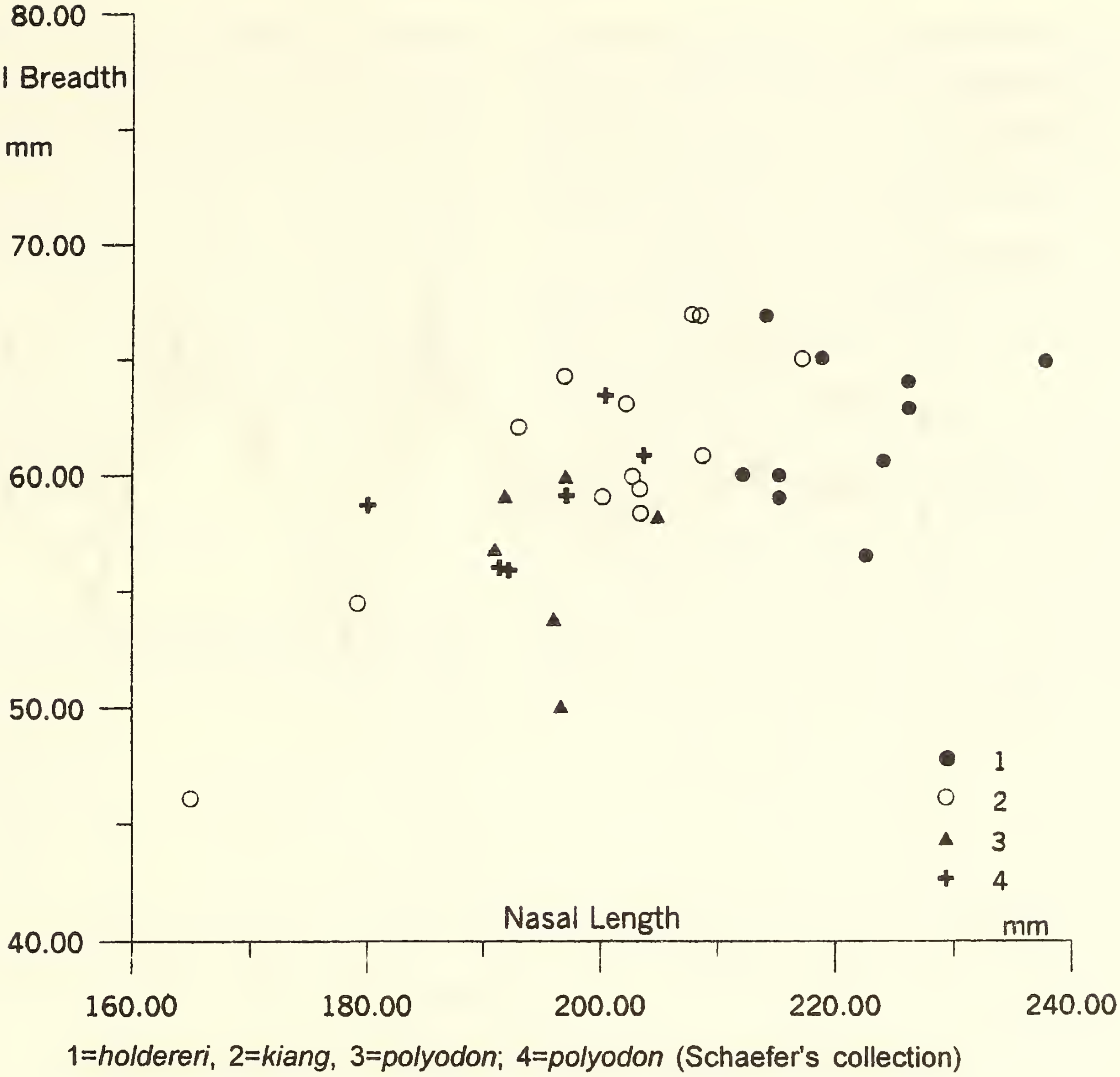


Fig. 3: Skull measurements of kiangs: nasal breadth vs nasal length, based on Fig. 12 in Groves and Mazák (1967), with additional skull data of the Southern kiang

We found the shape of the face in lateral view slightly more box shaped in the Southern kiang and more inclined in the other kiangs.

Among the 7 skulls of adults of the Schaefer collection, 5 have at least one 7th tooth (premolar P1) in the upper jaw. Groves and Mazák (1967) examined the presence of P1 in different equid species and they too found a high ratio (8 in 11) of kiangs with presence of P1.

MORPHOLOGY

In the ZMB exhibit, there is a mounted kiang group (male, female and foal) which could not be identified so far, as none of the museum documents mention this kiang group (Plate 2, Fig. 1). However, with the help of a newspaper article (A.C.L. 1940) we could confirm that a stallion, a mare and a foal of the 1938-39 expedition were indeed selected for dermoplastic modelling. J.M. Dolan (1999) misidentified this group as a member of the *holdereri* type from Schaefer's 2nd expedition.

The two adults within the mounted Southern kiang group in the ZMB have shoulder heights of 113 cm and 115 cm (our measurements).

The height at shoulder of dead specimens is given by Hodgson (1847a) as 3 ft 9 in. (114.3 cm) for a male, and 3 ft 5 in. (104.1 cm) for a female (printing error?), whereas Bailey (1910) gives 48.5 in. (123.2 cm) for a female. The mounted kiang in Leiden (collected by Hodgson) stands 117 cm tall at the shoulder (our measurement).

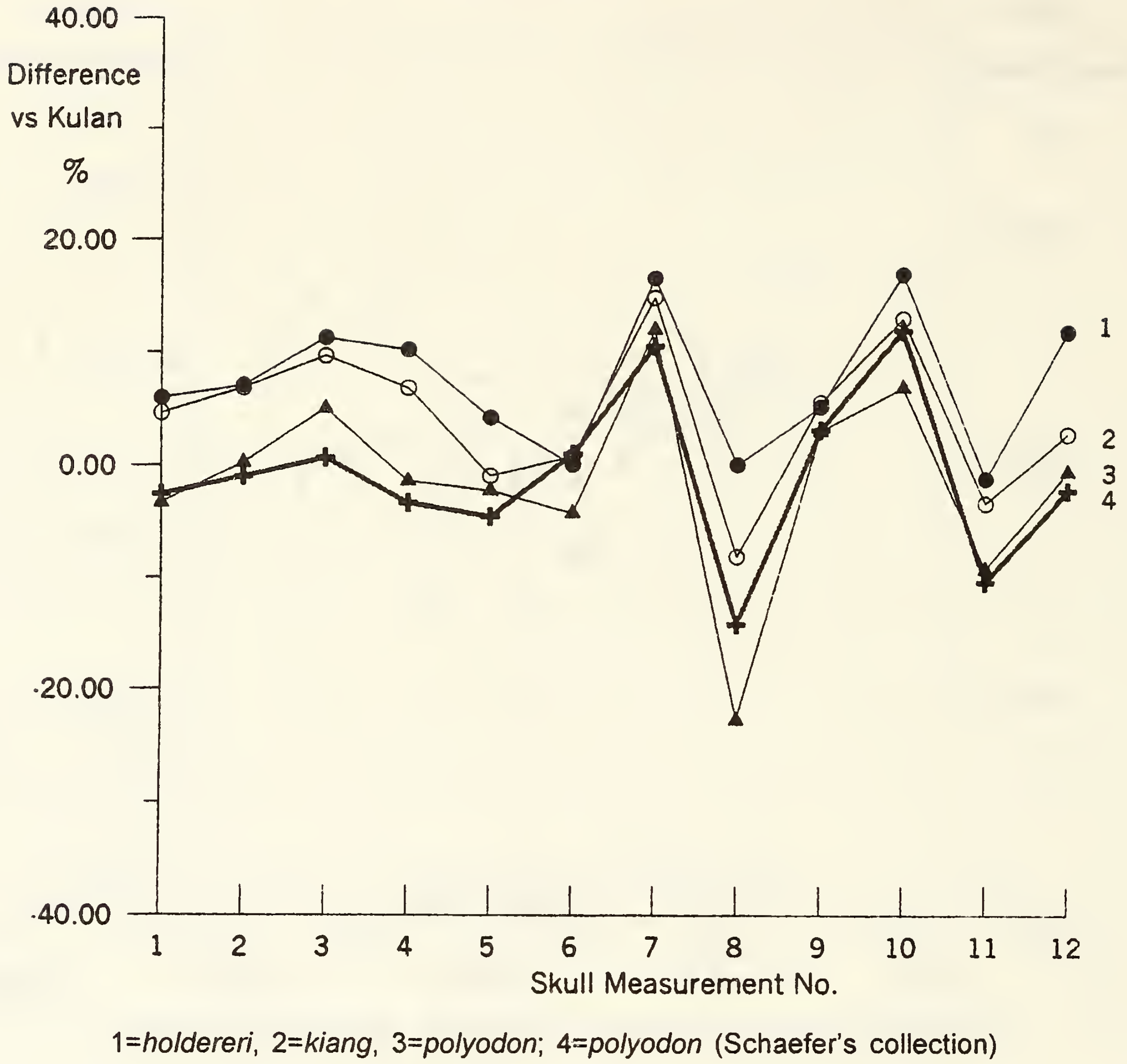


Fig. 4: Percent difference in average skull data of 3 subspecies of kiangs in comparison to *Equus hemionus kulan* at null axis, based on Table 2 [for measurement numbers see Table 1; kulan data taken from Groves and Mazák (1967)]

Although data taken on dead or mounted animals may differ slightly compared with data of live animals, it can be concluded from the available data that the Southern kiang has an average shoulder height between 110-120 cm (thus one of the smallest living wild equids).

Groves (1974) writes: "These southern kiangs, south of the upper Brahmaputra, are much smaller than the big north-eastern ones, only 100-115 cm high." He characterised the Western kiang as 135 cm high and of very dark colour and the Eastern kiang as 140 cm high and of light colour.

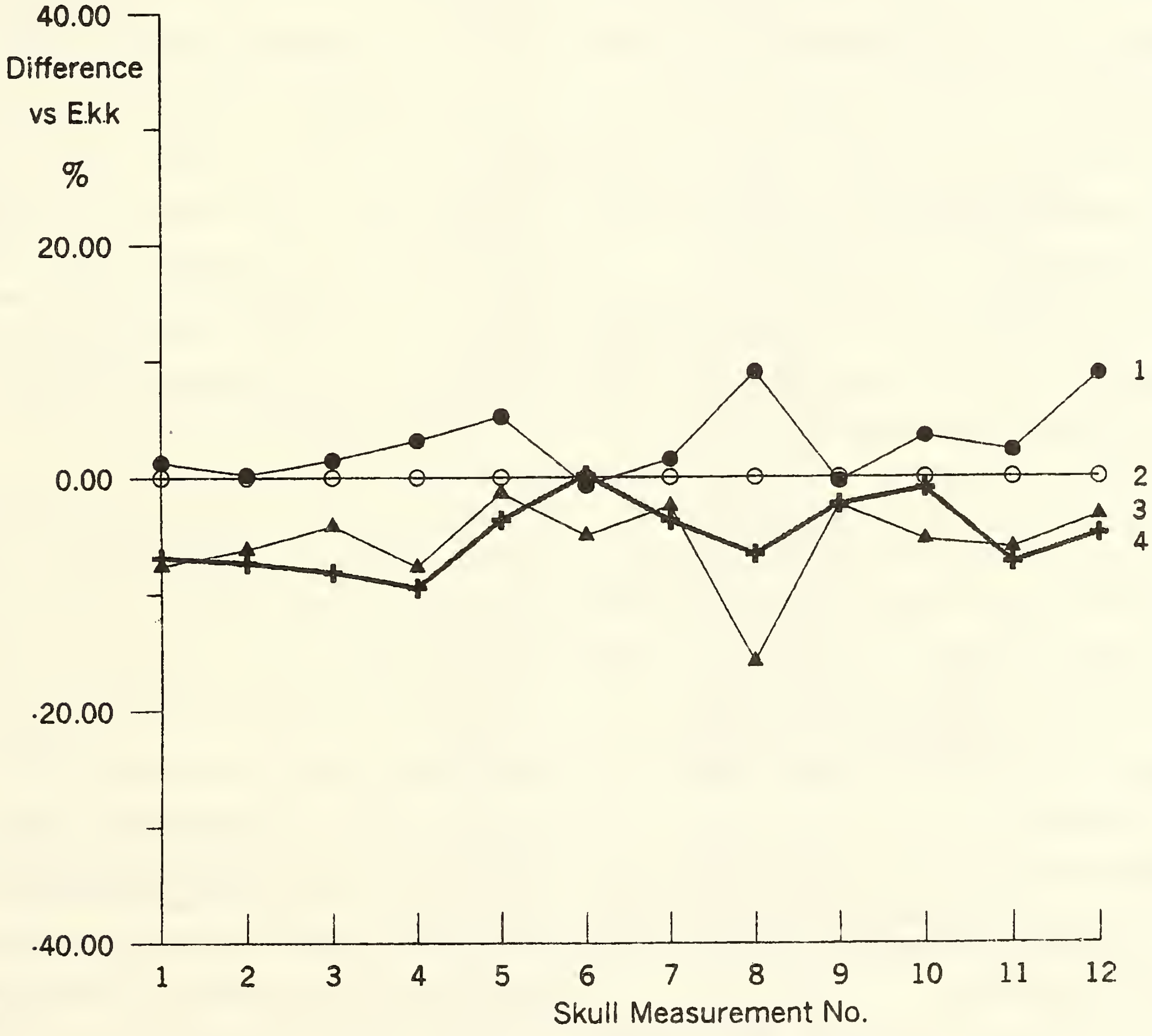
Schaller (1998) wrote: "I have observed the three supposed subspecies and noted no marked difference in size or colour. Although slight regional variation in kiangs may exist, an acceptance of subspecies seems premature." He photographed a group of 7 Southern kiangs in 1995 (erroneously printed: 1985) in the Chigo Co area, south of Lhasa (Schaller 1998, p. 169). Besides his photograph, we have seen very few pictures of the Southern kiang, as in Shah (1994, Plate 2) with a group of kiangs in the Bamchona area in northern Sikkim, a picture of a dead female and a foal in Bailey (1910, Plate A), and a group of animals in Schaefer (1950, opp. p. 128). A black and white film with the German title 'Geheimnis Tibet' shows some sequences with herds of kiangs, filmed by Schaefer's expedition in north Sikkim and south Tibet in 1938-39.

Mounted animals and skins in different museums are quite old and faded in colour and have not been thoroughly examined for this study. However, taking all impressions together, the Southern kiang appears to have a shorter brown elongation from the back down to the shoulder than the other kiangs, and thus larger white portions on the chest, a larger white wedge from the belly upwards to the shoulder and the outer sides of the front legs white. The white field on the flank is indistinct.

GEOGRAPHY

Historical sightings and descriptions: Only a very few kiangs of the southern range have ever been caught alive. Turner (1800) mentioned hearing that 4 kiangs were once in Warren Hastings' possession. It can be presumed that these were brought down by Bogle, who travelled to Teshu Lumbo (near Shigatse/ south Tibet) in 1774, commissioned by Hastings, the first Governor-General of Bengal, with an order to collect wild animals and seeds besides other rare goods.

Bailey (1910, 1911b) had reared two foals of the Southern kiang with the help of ponies as foster-mothers during his time as a trade agent in Gyantse. The Dalai Lama used to keep tame kiangs on a 'Wild Ass Meadow' between his summer residence and the state palace of his mother on the western outskirts of Lhasa (see map in Waddell



1=*holdereri*, 2=*kiang*, 3=*polyodon*; 4=*polyodon* (Schaefer's collection)

Fig. 5: Percent difference in average skull data of 3 subspecies of kiangs in comparison to the Western kiang (*Equus kiang kiang*) at null axis, based on Table 2 [for measurement numbers see Table 1]

1904). These semi-tame kiangs, three mares, allowed Walton (1905) to approach to within twenty yards (18 m) of them. Waddell (1905) mentioned that two of the kiang mares from the captive stock (of unknown origin, maybe even crossbreeds of different captive subspecies) of the Dalai Lama were taken as a present to King Edward VII. One mare was drowned while crossing the Tsangpo (Brahmaputra), the other landed safely in England in January 1905 and died, according to Dolan (1999), in 1915. A skull from "near Lhasa" (BM 5.6.20.1, listed by Lydekker 1916), possibly that of the drowned animal (same presenter for live and dead specimen: G.R. Macdonald), was examined by Groves and Mazák (1967) and described as follows: "though most like *holdereri*, does not fit satisfactorily into the race because of its (the specimen's) very long basal length, proportional to greatest length: a feature observed in *polyodon* as well. It may therefore be suggested that the specimen is a member of basically *holdereri* population affected by some intergradation with *polyodon*."

We investigated many old travel reports in the area south of latitude 32° N and determined the locations of historical kiang sightings as far back as possible. Recent references were also included. The locations, coordinates and references of kiang observations supposed to belong to the southern subspecies range are summarised in Table 3a, the information of other possible kiang sightings, in Table 3b. We have included available data from the year 1774 onwards. The coordinates are given, with a few exceptions, as precisely as kiang observations could be localised.

Geographical distribution: Our map (Fig. 6) shows the recorded kiang sightings, according to Tables 3a and b, with our interpretation of the distribution boundaries.

The northern boundary of the Southern kiang's geographical distribution is either the upper Brahmaputra (Tsangpo) or perhaps the Nyenchen Tanghla Mountain Range to the north of that river. It can be seen that *polyodon* might have its western and northern distribution boundaries at 88° E and at 29° N (except one location east of Lhasa). The kiangs west of 88° E and between 28° N and 29.5° N need to be specially investigated (our suggestion), for finding out which subspecies they really belong to. Another suggestion is that if Southern kiangs inhabit Bhutan at all, they should be looked for in the extreme northeast.

If the gap in the kiang distribution south of the Brahmaputra, between 87°-88° E, proves to be true, it could be explained by the glaciation history in the area of the Upper Arun and its tributaries. Evolution of subspecies is usually an effect of long-term isolations between populations. The separation of the Southern kiang from the other kiangs was possibly caused by glacio-tectonic forces during the Pleistocene or Late Glacial period. Kuhle (2001) explains that big ice sheets must have existed in south Tibet due to the damming effect of the Himalayan mountain wall, which found their drainage via the steep south slopes. The glaciation of the Arun river valley, between Mt Everest and Kangchenjunga, is confirmed by glaciogeological findings.

Our map (Fig. 6), which is based on more recorded kiang sightings than any previous distribution map, is in agreement with the map of Schaller (1998, p. 164), regarding a continuous east-west extension from the western towards the eastern kiangs. While Schaller also connects the southern distribution range with that of the other kiangs, Groves (1974, p. 95) as well as Denzau and Denzau (1999, p.50 and back cover) keep the southern subspecies geographically apart. Groves (1974), in his map, left a big gap between the eastern and western subspecies, but allowed the range of the Eastern kiang to meet that of the Southern kiang along the Brahmaputra. It seems that Groves (1974), as well as Groves and Ryder (2000), when including the Lhasa district in the geographical range of *holdereri*, have used the skull BM 5.6.20.1, mentioned earlier, for this claim. Our

Table 3a: Locations of sightings of southern kiangs

Location	Coordinates	Reference
Bam-tso	28.1° N, 89.3° E	Howard-Bury 1922
Bhomtso	28.1° N, 88.8° E	Hooker 1855
Bomchho La =Bamchhola	28.1° N, 88.7° E	Ali 1981, Lachungpa 1994, Shah 1994, Avasthe and Jha 1999
Chho Lhamu =Cholamoo Lake	28.0° N, 88.8° E	Campbell 1852, Ali 1981, Lachungpa 1994, Shah 1994, Ganguli-Lachungpa 1999, Avasthe and Jha 1999
Chhomodo	28.1° N, 88.7° E	Shah 1994
Chigo Co	28.7° N, 91.7° E	Schaller 1998
Chulung Valley, Chhulung La	28.1° N, 88.6° E	Shah 1994, Avasthe and Jha 1999
Chumulari - Phari	27.8° N, 89.2° E	Campbell 1848, Campbell 1852
Dingcham Province*		Hooker 1855
Dinggye	28.3° N, 88.1° E	Zhang 1997
Dochen	28.1° N, 89.3° E	Bailey 1910
Donkyala	28.0° N, 88.8° E	Shah 1994
Geree	28.2° N, 88.5° E	Campbell 1852
Gurudongmar	28.0° N, 88.7° E	Shah 1994
Gyakang =Gayokang	28.0° N, 88.6° E	Schaefer SIII, Schaefer 1950
Gyam-tso-na =Gyamchhona =Yeumtso	28.1° N, 88.6° E	Campbell 1852, White 1909, Schaefer 1950, Avasthe and Jha 1999
Gyisum - Nyala La	28.1° N, 92.2° E	Bailey 1957
Kala Lake	28.3° N, 89.5° E	Schaefer 1950
Kala Lake - Sameda	28.3° N, 89.6° E	Schaefer 1950, Schaefer SIII
Kamba-jong	28.3° N, 88.5° E	Campbell 1852, Walton 1905
Kangmar	28.5° N, 89.7° E	Bailey 1911a
Keraang, east of Chho Lhamu	28.0° N, 88.8° E	Lachungpa 1994, Shah 1994
Khamba (coming from Lake Teltung)	28.4° N, 88.4° E	Das 1902
Khongjakna (east of)	28.0° N, 88.9° E	Shah 1994
Kiang-lah mountains (running east-west at)	28.3° N, 88.2° E	Hooker 1855
Kurma	28.5° N, 88.7° E	Das 1902
Lapshi	28.2° N, 92.4° E	Bailey 1957
Lungma (east of)	28.3° N, 88.7° E	Denman 1954
Mendza (from Tangla to)	28.4° N, 89.6° E	Bailey 1911a
Nyala La (northeast of Tsöna)	28.2° N, 92.2° E	Bailey 1915
Oleten	28.0° N, 88.8° E	Shah 1994
Pawhunri base	28.0° N, 88.9° E	Kellas 1912
Sese La	28.0° N, 88.8° E	Lachungpa 1994, Shah 1994, Avasthe and Jha 1999
Sham-chu Pelling	28.2° N, 89.4° E	Bogle 1774 in: Markham 1876
Tangla	27.9° N, 89.2° E	Turner 1800
Tang La - Tuna	27.9° N, 89.3° E	Hayden and Cosson 1927, Schaefer 1950
Tratsang - Pu La	28.8° N, 92.3° E	Bailey 1957
Tulung La (southeast of Tsöna)	27.9° N, 92.2° E	Bailey 1915
Tuna	28.0° N, 89.2° E	Waddell 1905, Walton 1905
Tuna - Dotschen	28.0° N, 89.3° E	Hayden and Cosson 1927, Schaefer 1950
Uyu La - Yamdrok Tso	28.6° N, 90.7° E	Bailey 1924
Vi-si-king	29.7° N, 92.1° E	Hodgson 1832
Yamdrok Co	28.8° N, 91.4° E	Schaller 1998
Yumchho	28.0° N, 88.7° E	Avasthe and Jha 1999

*skirts the frontier of Sikkim, Bhutan and Nepal

Table 3b: Locations of sightings of (possibly) other kiangs south of latitude 32° N

Location	Coordinates	Reference
Baingoin	31.7° N, 89.8° E	Zhang 1997
Daggtse-tso	31.8° N, 87.3° E	Hedin 1903
Dschandin-tso	31.7° N, 85.4° E	Hedin 1903
Garing Cho (east side)	32.0° N, 89.2° E	Littledale 1896
Jaggju-rappga/Selling-tso	32.0° N, 88.8° E	Hedin 1903
Kjangdam	30.2° N, 87.0° E	Hedin 1909-1912
Langkar Mo	31.6° N, 87.5° E	Bower 1894
Mar-khung - Gemar	31.2° N, 87.1° E	Hayden and Cosson 1927
Mustang (Chhujung and Damodar Kunda)	29.3° N, 84.0° E	Anon. 1999
Nagmo	32.0° N, 86.8° E	Bower 1894
Namru region	31.7° N, 90.2° E	Hayden and Cosson 1927
Nam Tso (east of)	30.8° N, 91.1° E	Hayden and Cosson 1927
Ngang-Tsi Tso (northern shore)	31.2° N, 87.0° E	Hayden and Cosson 1927
Nyalam (villages: Ngora, Khoryak)	28.2° N, 85.9° E	Jackson 2000
Pegu Tso	29.0° N, 85.6° E	Jackson 1991
Shen-tsa - A-chen-tsongo	30.9° N, 88.8° E	Hayden and Cosson 1927
Takbur-La	29.4° N, 85.1° E	Hedin 1909-1912
Tarbar ('Moskitolager' east of)	30.1° N, 84.0° E	Landor 1898
Tong-chu (south of)	31.8° N, 89.2° E	Hayden and Cosson 1927
Xainza	30.9° N, 88.7° E	Zhang 1997
Xixabangma (northern flank)	28.5° N, 85.8° E	Zhang 1997
Zhongba	29.7° N, 84.1° E	Zhang 1997

careful investigations show that the distribution boundary of *holdereri* does not touch Lhasa, but remains about 110 km further north. The sighting of a kiang east of Lhasa and north of the Brahmaputra (as reported to Hodgson in 1832) remains uncertain regarding the subspecies question and is perhaps a doubtful point in our Southern kiang distribution map (Fig. 6). However, we did not want to exclude any information. With the help of our documentation it will be easier to re-interpret the subspecies distribution data in future, if more facts are ascertained.

PRESENT SITUATION

Official conservation status (for *Equus kiang* in general): in China it is listed in first category of the State Key Protected Wildlife List (Wang 1998), in India in Schedule 1 of the Wildlife (Protection) Act, 1972 (Agrawal 1994). The Southern kiang is listed as 'DD' (Data Deficient) in the '2000 IUCN Red List of Threatened Species' (Hilton-Taylor 2000), but deserves a threatened classification as endangered 'EN C2a', since the total population is estimated to number less than 2,500 mature individuals, severely fragmented, with no subpopulation estimated to contain more than 250.

Partial population estimates: Today's population density of the Southern kiang is largely unknown and only a few authors have published their observations.

Schaller (1998) mentioned, "During a wildlife survey in October 1995 we attempted to delineate current distribution between the Bhutan border and the Yarlung Tsangpo. According to local people, the kiangs were exterminated in most areas between the 1960s and 1980s. In that eastern part of their range we found kiangs around Chigo Co in three populations totalling probably no more than 200 animals; and others persist just south of Yamdrok Co."

Ali (1981) had reported two kiang groups (consisting of 10 and 7 individuals) during his

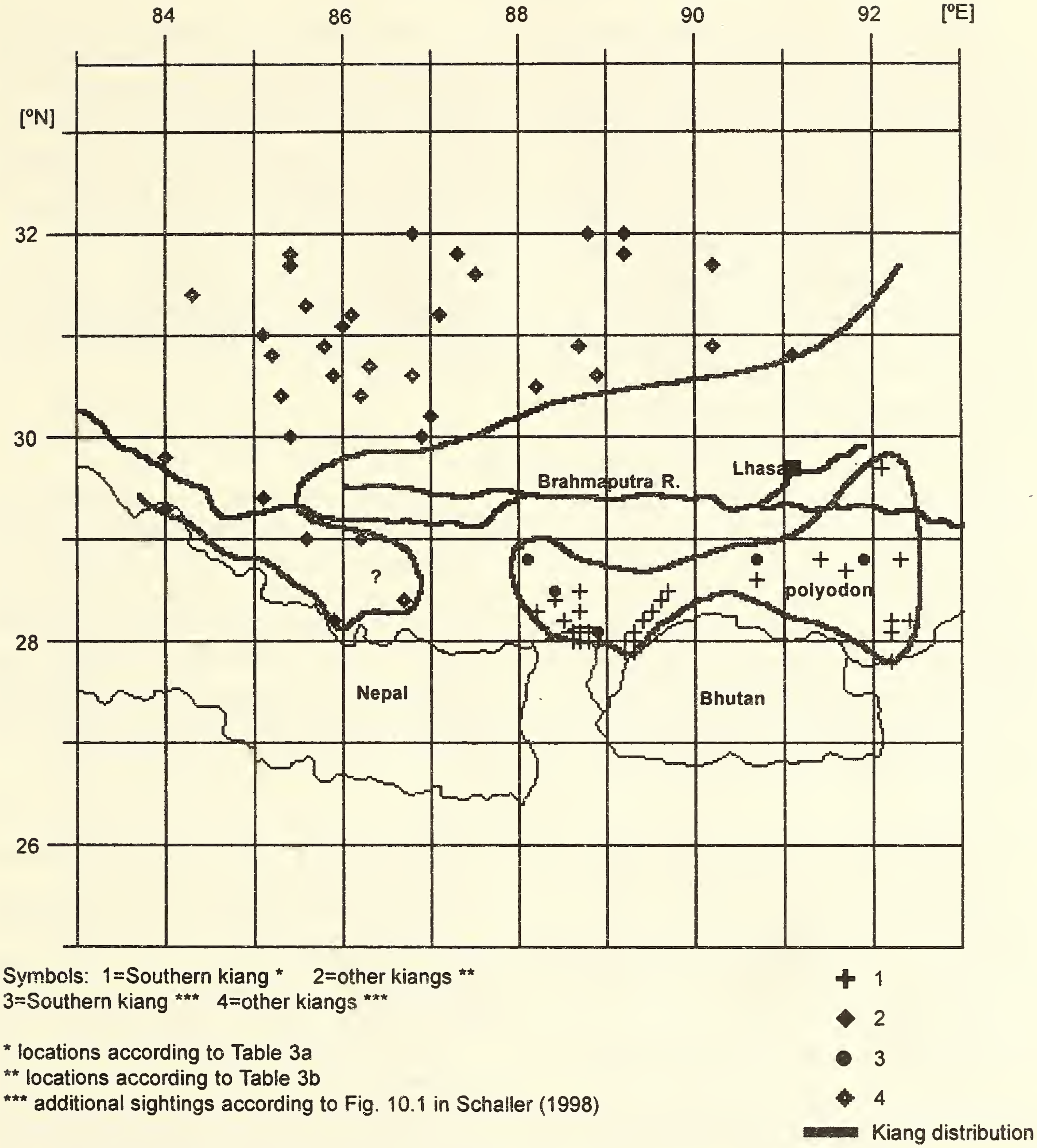

84
86
88
90
92
[°E]
[°N]
32
30
28
26
Brahmaputra R.
Lhasa
polyodon
?
Nepal
Bhutan
Symbols: 1=Southern kiang * 2=other kiangs **
3=Southern kiang *** 4=other kiangs ***
* locations according to Table 3a
** locations according to Table 3b
*** additional sightings according to Fig. 10.1 in Schaller (1998)
✚ 1
◆ 2
● 3
◆ 4
Kiang distribution

Fig. 6: Recent and historical sightings of kiangs in southern Tibet, Nepal and Sikkim (between 27°-32° N and 84°-93° E) with proposed distribution boundaries for the Southern kiang

ecological studies in north Sikkim in summer 1978 and summer 1979.

Lachungpa (1994) summarised her few kiang observations during 9 visits (4 without any kiang sightings) to north Sikkim during a period of 5 years (September 1989 - September 1994). Her list shows a total of 52 kiangs in 5 groups (group size ranging from 4 to 16). She estimated no more than 10-40 seasonally free-ranging Southern kiangs in Sikkim.

Shah (1994), while conducting a survey in north Sikkim between October 29 and November 15, 1994, counted a total of 74 kiangs in 14 groups (group size ranging from 1 to 48). Taking additional sightings by army personnel into account, she estimated a total population of 74-120 Southern kiangs in Sikkim and the adjacent areas of China. Interviewing the local nomads, she came to know that kiangs are sighted all year round.

Threats: Mahapatra (1998): "In 1962 the Indian Army was invited over to Sikkim, and has remained in border areas inaccessible to most researchers. Landmines have been laid in many patches in these areas. This has not only prevented study of rare animals like the kiang, but also led to decimation of its population. According to army officials, the three-strand barbed wire fencing around landmined areas has been damaged at many places in Dongkung-Chho Lhamo. But these patches of lush green grass attract kiangs and locals have often reported seeing kiangs being blown apart by landmines."

Also, Raj (1999) describes the minefields between China and India along the Sikkim border as the main casualty factor for rare wildlife including the kiang: "villagers have reported seeing herds of wild animals charging across the Tibetan border after being fired at by Chinese soldiers only to meet their end in the Indian minefields." Lachungpa (1994) mentioned the sighting of a lame kiang with the remark "land-mine casualty."

Natural calamities include high snowfall in winter and predation of foals by wolves. Domestic livestock is a serious grazing competitor (Shah 1994).

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TAXONOMY OF UNGULATES OF THE INDIAN SUBCONTINENT

Colin Groves[1]

Key words: Artiodactyla, Perissodactyla, taxonomy, Indian subcontinent, *Equus khur*, *Moschus cupreus*, *Muntiacus vaginalis*, *Cervus wallichii*, *Cervus hanglu*, *Capricornis thar*, *Tetracerus quadricornis*, *Gazella bennettii salinarum*

The ungulates of the Indian Subcontinent are remarkably diverse taxonomically and, despite their conspicuous nature, much remains to be learned about them. Their diversity appears to have been considerably underestimated, at both specific and subspecific level. Here, I argue that in historic times the Subcontinent has been home to 46 ungulate species. Three of these species (*Equus hemionus*, *Rhinoceros sondaicus* and *Bos javanicus*) are probably extinct. Six taxa, commonly regarded as subspecies of other species, I here raise to specific rank, or have done so very recently elsewhere: *Equus khur*, *Moschus cupreus*, *Muntiacus vaginalis*, *Cervus wallichii*, *Cervus hanglu* and *Capricornis thar*. Twenty-four species are polytypic; of these, eight are more widespread species represented by a single Subcontinental subspecies, but the remaining 16 show subspecific diversity within the Subcontinent itself. I describe one new subspecies, *Gazella bennettii salinarum*, and recognise three subspecies (for which names already exist) in *Tetracerus quadricornis*, a species previously thought to be monotypic.

Introduction

Over the hundred plus years of its existence, the Bombay Natural History Society has seen vast changes in its political and social setting, its clientele and its very rationale for existence. It has survived the demise of shikar and of British India, the dismembering of the polity that nurtured it, and even the change of name of the city that forms its base. In the meantime, the *Journal* of the BNHS has progressed from being a vehicle for documenting the fauna and flora of the Indian Subcontinent to its present status as the premier voice for knowledge, understanding and conservation of the Subcontinent's wildlife, both nationally and internationally.

In the midst of all these changes, we should not assume that the Society's original mission, that of documenting the fauna and flora of the Subcontinent, is complete. There is much to be learned, as I hope to show, about even the largest species of fauna, the ungulates. Again, while the original three countries of the Subcontinent (India, Nepal and Bhutan) have become divided into six, with the creation first of Pakistan and Sri Lanka and later of Bangladesh, these six countries share a common wildlife heritage, and I treat them together here.

The object of this centennial contribution, then, is to gather together information on the taxonomy of the ungulates of the Subcontinent, and to try to document exactly what it is that we know or do not know about this small but important corner of its biodiversity.

Taxonomy

Taxonomy, the science of biological classification, is still undergoing a wide-ranging rethink of its basic premises. A classification is an "information retrieval system", but exactly what information is it that we want to retrieve? Most practising taxonomists today would say that they want to try and incorporate information about evolution into their classifications, because this allows us to make predictions: if certain taxa share a common ancestor, their behaviours, their ecology and other aspects of their biology will be

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modifications of those of this ancestor. About how we might incorporate evolutionary information, however, there is as yet no consensus, although it can be argued that a new one is emerging.

Genera and higher categories: It is by now widely accepted that taxa of the genus-group and above should represent phyletic lineages. To place species A and B in one genus, and C in another, is to say that A and B share a common ancestor which is not shared by C.

The remaining controversy concerns how we should decide what ranks we should use. At present, this is purely arbitrary, often based on no more than tradition. Goodman *et al.* (1998), in the context of Primate taxonomy, have proposed to link taxonomic rank with time since divergence, and recently Groves (2001), citing some data on fossil ungulates, suggested slight modifications to this. A genus, in this scheme, would have a time depth of about 4-8 million years, a family, of 18-24 million. Subfamilies, tribes and subtribes would remain categories of convenience, as would subgenera: they would be used if subdivisions were needed, regardless of the exact times.

The Goodman *et al.* (1998) proposals are well worth considering; they would bring a much-needed objectivity into higher-category taxonomy. For the moment, however, we need more information on splitting times of lineages; this is a task for the future, and in what follows I have not made any drastic proposals for altering conventional genera.

Species: It is generally not possible to apply the well-known Biological Species Concept, whereby species are defined as being reproductively isolated. If two populations are sympatric and do not interbreed, this is of course unassailable evidence that they are different species; but what if they are allopatric, as closely related populations usually are? There is in this case no objective criterion beyond the opinion of some "expert" of whether they would or would not be likely to interbreed if their ranges were to meet.

Many taxonomists now adopt the Phylogenetic Species Concept, whereby species are defined as being diagnosably different: that is to say, that every individual can be differentiated on at least one heritable feature (see Groves 2001). This substitutes 'genetically isolated' for 'reproductively isolated', and switches the focus to the pattern (which we can observe) and away from the process (which we can only infer, and which may have brought it about). Under this concept, some species are recognised that have hitherto been regarded as only subspecies: a small price to pay, one might say, for objectivity. In what follows, application of this fresh view of species has led to a drastic revision of species boundaries in *Equus, Cervus, Capricornis* and *Nemorhaedus.*

Subspecies: Some taxonomists do not think it worthwhile recognising subspecies: two populations are either diagnosably distinct, in which case they are different species, or they are not. Yet I think there is still value in distinguishing two populations which are different as a whole, but do overlap to some extent. Their gene pools are distinct, and they are of conservation concern (for example).

Exactly how distinct should their gene-pools be to merit subspecific rank? We must not try to be too rigid about this; the rule that says that 75% of individuals of one subspecies must be distinguishable from all individuals of other subspecies (the 75% rule) is a good guideline. We can say no more than that.

It is mandatory, of course, that subspecies be geographic segments of a species. The category should not be misused to designate conspicuous morphs (colour, karyotype, etc.) that occur within populations.

Synonymy: Among junior synonyms, only those described for the Subcontinent are listed here. Author, date and type locality, but not full bibliographic reference, are given.

Order Proboscidea
Elephants

FAMILY ELEPHANTIDAE

Genus *Elephas* Linnaeus, 1758

Elephas maximus Linnaeus, 1758. Asian elephant

Elephas maximus maximus Linnaeus, 1758.

1758 *Elephas maximus* Linnaeus. "In Zeylonae paludosis ad amnes" (in the marshes of Ceylon by rivers). Restricted to rain forests of Sabaragamuva by Deraniyagala (1939).

1797 *Elephas indicus* G. Cuvier. Deraniyagala (1955) states that this was based on a specimen from Ceylon (Sri Lanka), but an examination of Cuvier's description does not bear this out.

1797 *Elephas asiaticus* Blumenbach. Asia, chiefly Ceylon.

1845 *Elephas indicus bengalensis* de Blainville. Ganges in Bengal.

1845 *Elephas indicus ceylanicus* de Blainville. Ceylon.

1940 *Elephas maximus vilaliya* Deraniyagala. Manampitiya, floodplain of Mahavili, eastern Ceylon.

1950 *Elephas maximus dakhunensis* Deraniyagala. Travancore.

Deraniyagala (1955) distinguished two subspecies in Sri Lanka and two on the mainland of the Subcontinent. *Elephas maximus vilaliya*, which he calls the giant Ceylon swamp elephant, is restricted to the Mahavili floodplain, and is distinguished from the smaller nominotypical *E.m. maximus*, which is the widespread form, by its larger size and associated skull shape differences. The food supply on the Mahavili floodplain is exceptional; one must be cautious about recognising a separate subspecies based almost entirely on size and size-dependant features under circumstances where phenotypic plasticity is so likely to be involved. Sri Lankan elephants differ from Indian in their general tusklessness, as male Indian elephants generally have tusks (see next para). Most Sri Lankan elephants are rather small, but Mahavili ones can be larger than mainland ones.

Deraniyagala's mainland subspecies were differentiated on the basis of tusk development and the degree of depigmentation on the ears and face. In *E.m. dakhunensis* 96% of the males are tusked, and depigmentation is "heavy and white", but in *E.m. bengalensis* only 51% of males have tusks, and depigmentation is "scanty and white"; in Southeast Asian subspecies over 90% of males are tusked, and depigmentation is scantier and grayer (less white) the further south one goes.

The information on the proportion of tusked males is interesting but cannot be of much value for differentiating subspecies, given that it concerns males only and the percentage differences are so slight (nowhere near the 'seventy-five percent rule' described above). The amount of depigmentation may be more cogent. All Asian elephants undergo some facial and ear depigmentation with age, and it is, in my experience, notably heavier at any age in Indian than in Southeast Asian elephants, but there is a great deal of overlap between northern and southern Subcontinent elephants. For the moment, no subspecies are recognised in the region, though Indonesian/Malaysian (*E.m. sumatranus*) and probably mainland Southeast Asian (*E.m. birmanicus*) subspecies would be worth recognising at least provisionally.

Order Sirenia
Seacows

FAMILY DUGONGIDAE

Genus *Dugong* Lacépède, 1799

Dugong dugon (Müller, 1776). Dugong

1776 *Trichecus dugon* Müller. Cape of Good Hope to Philippines.

1799 *Dugong indicus* Lacépède. Indian Ocean.

There appears to be no study to examine whether any geographic differentiation exists between Red Sea, Indian Ocean and Australasian dugongs.

Order Perissodactyla
Odd-toed ungulates

FAMILY EQUIDAE

Genus *Equus* Linnaeus, 1758

Equus kiang Moorcroft, 1841. Kiang or Tibetan wild ass

The kiang has a large head and thick muzzle; relatively long mane; and long hairs not restricted to tail tuft but extending some way up either side of tail. The demarcation pattern between contrasting dark (reddish) body blocks and white underside is oblique from stifle (knee joint) to croup (rump), and the white rump patch is infused with the reddish tone of the haunch. The dorsal stripe is thin and never bordered with white; it extends to tail tuft. A dark ring round hoof. Ear 165-178 mm long.

Skull resembles *E. hemionus*, except that incisors tend to sit more vertically in the jaws (except in aged individuals, in which alveolar recession tends to reveal the oblique roots), and highest point on cranial profile is often directly above the posterior rim of the orbit, instead of behind it.

Equus kiang kiang Moorcroft, 1841

1841 *Equus kiang* Moorcroft. Eastern parts of Ladakh.

Size large, skull length 492-537 mm (n=15). Range in Subcontinent: Ladakh.

Equus kiang polyodon (Hodgson, 1847)

1847 *Asinus polyodon* Hodgson. Tibet, just north of the Sikkim border (fixed by Groves and Mazák, 1967).

1959 *Hemionus kiang nepalensis* Trumler. "Nepal"; more probably the region of Tibet just north of the Sikkim border (see Groves and Mazák, 1967, who discuss the status of the skin and skull of the type specimen).

Size very small, skull length 473-494 mm (n=7), but nasals and toothrow as long as in other kiangs. Range in Subcontinent: Sikkim.

Equus hemionus Pallas, 1775. Onager or Asian wild ass

Mane very short, "clipped"; dorsal stripe thick, bordered with a white line on either side; white of rump is not infused; demarcation between the reddish flank block and whitish underside runs parallel to the body outline, before turning sharply up towards the dorsal stripe. A dark ring round hoof. Nasal bones relatively straight. Skull resembles *E. kiang*.

Equus hemionus blanfordi (Pocock, 1947)

1947 *Microhippus hemionus blanfordi* Pocock. Sham Plains, Quetta, Baluchistan.

This grayish subspecies was unusual in *E. hemionus* in that the dorsal stripe did not reach the tail-tuft. Skull length 484-498 mm (n=2). It is now extinct; I have seen only two specimens, one from the type locality, and the other from Kandahar in Afghanistan.

Equus khur Lesson, 1827. Khur or Indian wild ass

1827 *Equus khur* Lesson. Little Rann of Kutch (fixed by Groves and Mazák, 1967).

1862 *Asinus indicus* George, 1869. India.

The khur is sharply distinct from *Equus hemionus*, and we cannot now tell whether the two intergraded; at any rate, the extinct Baluchistan subspecies of *E. hemionus* (see above) was not intermediate, except possibly in the failure of the dorsal stripe to extend to the tail-tuft. In *Equus khur* the coloured blocks on flank and haunch are very small, so the predominant colour is white, and lower 45% or more of flank is whitish; demarcation on the lower haunch slants upward from front (stifle) to back. Dorsal stripe with a clear white border on either side; this becomes obfuscated with age, but probably never entirely disappears. White wedge between haunch- and flank-blocks nearly or fully reaches spine. Legs pure white. White zone on muzzle occupies nearly 40% of snout-to-ear distance. Dorsal stripe fades out halfway down tail. No dark ring round hoof. Nasal bones raised (making whole facial profile strongly concave); skull short [length, male 493-519 mm (n=3), female 468-511 mm (n=6)], with small teeth, noticeably high-crowned. Choanae small. Orbits high. Metapodials less elongated than *E. hemionus*. Ear very long, 187-210 mm.

The khur still occurs in the Little Rann of Kutch. I have seen a specimen from Thar Parkur, Sind, where it is now extinct.

FAMILY RHINOCEROTIDAE

Genus *Rhinoceros* Linnaeus, 1758

Rhinoceros unicornis Linnaeus, 1758. Indian/ Great one-horned rhinoceros

1758 *Rhinoceros unicornis* Linnaeus, 1758. Rookmaaker (1998) shows that this name was based on the same specimen from which Albrecht Dürer's famous woodcut was taken. He suggests restricting the type locality to Assam.

1817 *Rhinoceros indicus* G. Cuvier.

1830 *Rhinoceros asiaticus* Blumenbach.

1867 *Rhinoceros stenocephalus* Gray. Asia.

1876 *Rhinoceros jamrachi* Sclater. Manipur. Contra Rookmaaker (1983), I would consider that the original description, that of Jamrach (1874), does not truly count as a "publication."

The historical distribution of this species extended from the upper Brahmaputra, on (and beyond) the Burmese border, along the Ganga-Brahmaputra system to the Indus and its tributaries, as far west as the Khyber Pass (Rookmaaker 1980, Rookmaaker 2000).

In the multivariate analysis of Groves (1993a), Nepalese and Assamese skulls are different. Those from Assam tend to have narrower zygomatic breadth but wider occiput and interorbital region. A single skull from Koch Bihar was more similar to those from Nepal. These findings should be tested on larger samples.

Rhinoceros sondaicus Desmarest, 1822. Javan/ Lesser one-horned rhinoceros

Rhinoceros sondaicus inermis (Lesson, 1840)

1840 *Rhinoceros inermis* Lesson. Sunderbans.

Broad across the zygomatic arches, and high occiput (Groves and Chakraborty 1983, Groves 1993a). The subspecies from the Sundarbans and neighbouring districts (including the Sylhet and Chittagong districts of Bangladesh, and Manipur, possibly also Bhutan and Sikkim: see Rookmaaker 1980) became extinct in the 1890s.

A skull from Moraghat, Bhutan Duars (where the species has been extinct since the 1870s), differs slightly from Sundarbans specimens, especially in its large teeth (Groves 1967).

Genus *Dicerorhinus* Gloger, 1841

Dicerorhinus sumatrensis (G. Fischer, 1814). Sumatran/Asian two-horned rhinoceros

Dicerorhinus sumatrensis lasiotis (Sclater, 1872)

1872 *Rhinoceros lasiotis* Sclater. Chittagong.

A large subspecies with large teeth and very broad, high occiput; molar teeth are large (Groves and Chakraborty 1983, Groves 1993a). Formerly occurred in the northeastern states of India and eastern Bangladesh, as far west as the Sankosh river, and North Cachar, Cachar and Hailakandi districts in Assam; it apparently still occurs in Manipur and Nagaland (Choudhury 1997).

Order Artiodactyla
Even-toed ungulates

FAMILY SUIDAE

Genus *Sus* Linnaeus, 1758

Sus scrofa Linnaeus, 1758. Eurasian wild pig (Indian wild boar of Prater, 1971)

Sus scrofa cristatus Wagner, 1839
1839 *Sus cristatus* Wagner. Near Calcutta (fixed by Groves, 1981).
1868 *Sus aper* var. *aipomus* Gray. Nepal. After a *nomen nudum* of Hodgson (1842).
1868 *Sus aper* var. *isonotus* Gray. Nepal. After a *nomen nudum* of Hodgson (1842).
1843 *Sus indicus* Gray. Nepal (fixed by Groves, 1981).
1847 *Sus affinis* Gray. Nilgiri Hills.
1851 *Sus zeylonensis* Blyth. Ceylon.
1860 *Sus bengalensis* Blyth. Bengal and Kutak.

Skull large (skull lengths of males in different populations average from 379 mm in Nepal to 414 mm in southern India), broad and high-crowned; mainly black, brindled with white, with a long mane all along the back. From the sub-Himalayan tract, from Punjab east to Nagaland, and south to Bihar, Madhya Pradesh and Kolhapur, Maharashtra.

Groves (1981) recognised a southern Indian and Sri Lankan subspecies, *Sus scrofa affinis*, but this differs from *S.s. cristatus* only in its larger size, and considering the known environmentally induced plasticity of size in pigs, the inference that the difference is genetic cannot be sustained. In addition, the wide variation in size in Sri Lanka covers both Indian "subspecies", and more.

Sus scrofa davidi Groves, 1981
1981 *Sus scrofa davidi* Groves. Sind.

A small-sized subspecies (adult males average 365 mm), with a low-crowned skull; colour light brown or yellowish, with long thick mane. From the dry country of northwestern India (Pune, Gujarat, Rajasthan) and Pakistan (Sind).

Sus salvanius (Hodgson, 1847). Pygmy hog
1847 *Porcula salvania* Hodgson. Sikkim Terai.
1863 *Sus lilliputensis* Gray. *Nomen nudum.*

A tiny species, shoulder height 230-305 mm in males, 200-216 mm in females. Dark brown with subterminal light hair bands, no mane, very short tail, and relatively long hindlegs compared to forelegs. The inner "false hoofs" are short compared to other pigs. A detailed description is given by Ghosh (1988), who supports restoring the genus *Porcula* Hodgson, 1847, for this species. Known in the past from the grass jungles of eastern Nepal, Sikkim, northern Bengal, Bhutan and western Assam; now known for certain only from Assam.

FAMILY TRAGULIDAE

Genus *Moschiola* Hodgson, 1843

Moschiola meminna (Erxleben, 1777). Indian chevrotain or Mouse-deer
1777 *Moschus meminna* Erxleben. Ceylon.
1842 *Tragulus mimenoides* Hodgson. Nepal Terai.
1843 *Meminna indica* Gray. Renaming of *meminna.*
1843 *Meminna malaccensis* Gray. Supposedly from Singapore.

The Indian mouse-deer, which lives in Sri Lanka, southern India and Nepal, has been poorly studied taxonomically, in contrast to the related Southeast Asian genus *Tragulus* in which dozens of subspecies have been described.

FAMILY MOSCHIDAE

Genus *Moschus* Linnaeus, 1758

According to the latest revision (Groves *et al.* 1995), four species of musk deer occur in the Subcontinent; three of these (the exception being

Moschus cupreus) extend into Sichuan and Yunnan, in China. Some new subspecies remain to be described in *M. leucogaster*; these may possibly prove to be distinct species. All species live at about 2,500 to 4,200 m above msl, in the Alpine zone. The undescribed species inhabiting Uttar Pradesh (areas now in Uttaranchal), Himachal Pradesh and western Nepal apparently lives in high-altitude forest at 2,500 to 3,000 m. The ecological differentiation between the two overlapping species of the Himalayan slopes, *M. leucogaster* and *M. fuscus*, is unclear. The Subcontinent has no lower-altitude species restricted to the lower montane forest zone, analogous to *M. berezovskii* of China.

Moschus chrysogaster Hodgson, 1839. Alpine/Golden-bellied musk deer

1839 *Moschus chrysogaster* Hodgson. "Nepal": probably from the Tibetan plateau.

1915 *Moschus cacharensis* Lydekker.

From eastern Nepal, Sikkim and Bhutan, entirely in the plateau zone, above the tree-line. Dark brown, intensely speckled with buff to golden ochre. Throat with a noticeable pair of yellowish longitudinal stripes or spot-rows; rump yellowish, paler than back; ears dark brown, speckled buff, outside, with pale tips; orange-ochrey inside and at base. Limbs becoming paler distally, until shanks are whitish. Underside paler, often yellowish; an orange eye-ring. Large size: metacarpal length 109-118 mm, metatarsal 128-138 mm. Hoofs are more elongated than other species, 27-29 mm (in other species, 24 mm).

Moschus leucogaster Hodgson, 1839. White-bellied musk deer

1839 *Moschus leucogaster* Hodgson. "Nepal," probably from the Himalayan slopes.

1839 *Moschus saturatus* Hodgson. "Nepal," probably from the Himalayan slopes.

Eastern Nepal, Sikkim and Bhutan, on the Himalayan slopes. Dark brown to agouti red above, with a yellowish tone on buttocks; belly pale grey; throat wholly whitish, or with a white sternal patch; limbs dark externally, with white speckling on inner surfaces and often on digits. Ears blackish, with very fine whitish speckling except at the tip which is wholly dark. Size large like *M. chrysogaster.*

Moschus sp. Kulu/Indian forest musk deer

The musk deer from Uttaranchal (erstwhile Uttar Pradesh) and Himachal Pradesh (Garhwal, Tehri, Chamba, Kulu, Kedarnath, Barinda Pass, Jaunsar) and western Nepal (as far east as Mustang) may be specifically distinct. Grubb (1982) cites field evidence from M.J.B. Green, R.M. Mitchell and others that there may be geographic overlap, with some elevational difference between light and dark musk deer, within Nepal, the grey ones being found in dense oak/rhododendron forests. Colour is pale grey, with at most a poorly defined browner, speckled saddle area; ears are bordered with white; the rump is entirely dark; the belly is white.

Moschus fuscus Li, 1981. Dwarf musk deer

From Assam west to the Mount Everest region of Nepal, again on the Himalayan slopes. Colour very dark above and below, the head, ears and legs being black, neck often lighter; throat dark often with two incomplete yellow "collars"; rump with ochrey tones, but black on buttocks. The smallest species: skull length less than 150 mm, nasals under 46 mm; metacarpal length 88-101 mm, metatarsal 126-135 mm.

Moschus cupreus Grubb, 1982. Kashmir musk deer

From Kashmir, at over 3,000 m above msl. Colour grey-brown, often vaguely spotted, with a coppery-reddish dorsal saddle; rump dark, grizzled grey; underside light grey; throat white; lower segments of limbs whitish. Ears dark brown, white at base, with frosted rims. Large species.

FAMILY CERVIDAE

Genus *Muntiacus* Rafinesque, 1815

Muntiacus vaginalis (Boddaert, 1785). Red/ Indian muntjac or Barking deer

Though conventionally placed in a single species, the red muntjac should preferably be split into at least two. Differences are marked and consistent, and their different karyotypes should reduce the fertility of hybrids between them (although one possible wild hybrid was described by Groves and Grubb, 1990). The present species, found in suitable country throughout South Asia and mainland Southeast Asia north of the Isthmus of Kra, differs from Indonesian/Malaysian *M. muntjak* in its chromosome number ($2n = 6$ in the female, 7 in the male, vs $2n = 8$ in the female, 9 in the male of *M. muntjak*), and in the relative lack of contrasts in colour, especially the absence of the median dorsal darkening of *M. muntjak*. The black-legged muntjac of the southern borders of China and neighbouring regions may constitute a third species of the red muntjac group.

Descriptions of subspecies are after Groves and Grubb (1990).

Muntiacus vaginalis vaginalis (Boddaert, 1785)
1785 *Cervus vaginalis* Boddaert. Bengal.
1827 *Cervus moschatus* Hamilton Smith. Not of de Blainville, 1816 (= *M. muntjak*).
1833 *Cervus ratwa* Hodgson. Nepal.
1840 *Cervus melas* Ogilby. Himalayas.
1845 *Cervus styloceros* Schinz. Renaming of *melas*.

Dark reddish dorsally, somewhat paler on flanks; nape slightly greyer; forehead and occiput light orange-brown, rest of face grayish; ear-backs reddish at base, remainder dark grey; limbs dark brown to grey; underside paler; groin and line on front of hindlegs, to hocks, white. Largest of the three subspecies of the Subcontinent, averaging about 200 mm skull length. Antlers 80-120 mm long; pedicels relatively long, averaging 125 mm. From Shevaroy Hills north to Nepal and Bhutan.

Muntiacus vaginalis aureus (Hamilton Smith, 1826)
1826 *Cervus aureus* Hamilton Smith. Some part of southern India.
?1844 *Cervus albipes* Wagner. Supposedly from Bombay and Poona. This name may actually be a senior synonym of *malabaricus*.
1872 *Cervus tamulicus* Gray. Deccan.

Pale yellowish on body and limbs; nape greyer; forehead and occiput pale orange-brown, rest of face light orange; ear-backs orange at base, becoming grey, and tips and rims may be dark grey; underside paler; a line on front of hindlegs, to hocks, white. Medium sized, skull length averaging 192 mm. Antlers short, 70-100 mm, pedicels about 110 mm. From Kumaun and Kheri, southeast to the Deccan.

Muntiacus vaginalis malabaricus Lydekker, 1915
1915 *Muntiacus muntjak malabaricus* Lydekker. Nagarhole.

Colour of body and limbs a washed-out reddish, with much greying on nape and back; underside drab; white area on inner and lower limb segments extending round to front of pasterns, restricting red to a narrow anterior band. Small, skull length averaging 178 mm. Antlers short, 60-100 mm, with short pedicels, only 100 mm. From Sri Lanka and southern India northwest as far as Pune.

Genus *Cervus* Linnaeus, 1758

This genus has usually been taken to include, as subgenera or species-groups, *Rusa* and *Rucervus* (and sometimes also *Axis* and *Hyelaphus*). Groves and Grubb (1987) pointed out that *Elaphurus* is the sister-group of *Cervus* s.s. (=sensu stricto), so if *Elaphurus* — a widely recognised genus — is to be retained, to preserve the monophyly of *Cervus* it is necessary to keep *Axis*, at the very least, separate (they included *Hyelaphus* in *Axis*); and, according to the arguments of Grubb (1990) and Geist (1998), *Rusa* and *Rucervus* should also be recognised as valid genera for the same reason.

The genus, thus restricted, has traditionally been considered to contain two species: *Cervus elaphus* (red deer, wapiti, shou, Kashmir stag) and *C. nippon* (the sika, of Japan and China). Geist (1998), however, has considered the interrelationships of the "elaphine deer" in some detail, and stressed the consistent differences in both morphology and behaviour between red deer and wapiti, which he clearly regards as distinct species (*Cervus elaphus* and *C. canadensis* respectively). Information on other elaphine deer is not adequate to determine their taxonomic status so clearly, but the two taxa from the Subcontinent are neither wapiti nor true red deer, though perhaps closer to wapiti. They belong to what Geist regards as the "primitive group", whose antlers are characterised by the bez tine being larger than the brow tine and by having a sharp bend at the 3rd tine (like wapiti in both characters), while retaining a primitive 5-tined plan; extra branching occurs in well-developed antlers, as is characteristic of all elaphine deer, but in these primitive taxa it takes the form of a transverse branching of the 4th tine, and occasionally of the 5th as well.

In these primitive elaphines, as Geist shows, no special summer coat is grown, so in summer they are just a faded version of the winter colour. Their small rump patches and short manes are also primitive, yet the very short tail, only half as long as the ear, is an advanced feature.

The rutting call, which is so different in wapiti and red deer, is different again in the primitive group. It begins in red deer fashion, with a closed-lips roar, then opens out as the lips are retracted to end in a wapiti-like bugle. Geist sees the group as adapted to saltatorial running on steep slopes in high mountain forests and among shrubs.

There is no sense in attempting to keep these primitive elaphines in the same species as wapiti, with which they admittedly share a few primitive retentions; still less as in the same species as red deer. Their primitive features are shared with a third taxon, *macneilli* from Sichuan. They nonetheless differ consistently from each other, and the radical step of regarding them as separate species seems unavoidable. Excellent colour photographs of them can be seen in Dolan (1988).

Cervus wallichii G. Cuvier, 1823. Shou

1823 *Cervus wallichii* G. Cuvier. Nepal; restricted to Mansarowar Lake, Tibet, by Lydekker (1915).

1841 *Cervus affinis* Hodgson. Supposedly from Sal Forest, Nepal, but more likely from Sikkim.

1850 *Cervus tibetanus* Hodgson. Lingmo, Phari, Dingcham, Tibet.

1851 *Cervus nariyanus* Hodgson. Western Tibet.

These are, according to Geist (1998), short-legged, broad-hoofed deer with long narrow ears and a large square muzzle. In winter, light sandy brown with a grey face, in summer fading to slate-grey. The large white rump patch extends upward on the croup and surrounds the short, white tail, and is sometimes partially divided by a very weakly-marked median line of the body colour; there may be a blackish edging infero-laterally. Chin and lips are grey or fawn; belly and inner surfaces of hindlegs grey. The short mane is the same colour as the body. Skull length of stags 432-481 mm (n=10); antler length (straight) of prime stags 800-1,040 (n=8), brow tine length 272-368 mm; the tip of the beam is longer than the 4th tine.

This species occurred in Sikkim on the Tibetan frontier (Chumbi Valley), and still occurs in Bhutan (Dolan 1988). It is uncertain whether the Tibetan (Upper Tsangpo) population (true *wallichii*) is the same as that of the Chumbi Valley (*affinis*), but it seems likely that the features of the rump patch, the only described difference, are variable.

Cervus hanglu Wagner, 1844. Kashmir stag

1844 *Cervus hanglu* Wagner. Kashmir.

1847 *Cervus casperianus* Gray. Kashmir.
1859 *Cervus cashmeriensis* Adams. Kashmir.

In winter, dark liver-brown, the legs and chest rather darker, and the face, neck and back usually lighter; in summer, fading to a relatively light tone with a sharply contrasting dark chest and limbs. Many females are spotted in summer. The narrow rump patch does not extend, or hardly extends beyond the tail root, is invaded by a wedge of body colour which may extend onto the tail, and is bordered infero-laterally by a black band. Chin, lips and inside of ears are white; belly, groin and inner surfaces of hindlegs whitish; a dark area on posterior belly. The metatarsal gland is creamy to light red. There is dark curly hair between the antler pedicels. Smaller than *Cervus wallichii*: skull length of stags 359-415 mm (n=8), but antlers relatively larger, straight length 752-1,053 mm (n=12), with shorter brow tine (229-315 mm); the tip of the beam is shorter or barely longer than the 4th tine. From the Vale of Kashmir and neighbouring regions, up to 3,600 m above msl; now restricted to Dachigam and Srinagar City Forest National Parks.

Genus *Rucervus* Hodgson, 1838

Regarded as a distinct genus, rather than a subgenus of *Cervus* or of *Rusa*, by Grubb (1990). The two species of the Subcontinent differ sharply in antler form, in the development of the lachrymal pit in the skull, and in the metatarsal tuft of *R. eldii.* However, they are clearly sister species, and the genus *Panolia*, erected for *R. eldii,* is not warranted.

Rucervus eldii (McClelland, 1842). Eld's/Brow-antlered deer

Rucervus eldii eldii (McClelland, 1842)
1842 *Cervus eldii* McClelland. Manipur.
1843 *Cervus frontalis* McClelland. Renaming of *eldii.*
1843 *Panolia acuticornis* Gray. Manipur.
1845 *Cervus lyratus* Schinz. Manipur.
1901 *Cervus eldi cornipes* Lydekker. Manipur.

A distinctive subspecies, differing from those in the Indo-Chinese region by its elongated, spreading hoofs with bare, cornified skin on the backs of the pasterns. It is restricted to the masses of floating vegetation called 'phumdi', in Logtak Lake, Manipur, where there are still under a hundred individuals, though it breeds well in captivity.

Rucervus duvaucelii (G. Cuvier, 1823). Barasingha or Swamp deer

Rucervus duvaucelii duvaucelii (G. Cuvier, 1823)
1823 *Cervus duvaucelii* G. Cuvier. Northern India (restricted to Kumaun by Groves, 1983).
1834 *Cervus bahrainja* Hodgson. Nepal.
1835 *Cervus elaphoides* Hodgson. Substitute for *bahrainja.*
1837 *Cervus smithii* Gray. Northern India (restricted to Kumaun by Groves, 1983).
1843 *Cervus dimorphé* Hodgson. Sal forests of the Morung, Nepal.
1850 *Cervus euceros* or *euryceros* Gray. India (restricted to Kumaun by Groves, 1983).
1868 *Cervus eucladoceros* Falconer. West bank of Ganges, south of Hardwar, United Provinces.*

A swampy-ground form, with splayed hooves and naked pasterns. Antlers long, slender, not compressed or palmated. Short nasals, rostrum slender (not deep). Little size difference between sexes; tail long, slender; ears large, rounded, with thick white hair inside. From Kumaun, Kheri, and southwestern Nepal; formerly extended east to Chitwan.

Rucervus duvaucelii branderi Pocock, 1943
1943 *Rucervus duvaucelii branderi* Pocock. Mandla, Madhya Pradesh.

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*area now in Uttaranchal

The hard-ground form, with "well-knit" feet and hair-covered pasterns. Body size smaller, with some sexual dimorphism, male with dark rutting pelage and prominent neck ruff; antlers very long, with long brow tine, many branches, branching high up the beam, with long anterior branch. Long nasals, short broad snout. Tail somewhat shorter; ears large, rounded, with thick white hair inside. Prominent white spots along dorsal stripe, especially during moult. Restricted to Kanha National Park.

Rucervus duvaucelii ranjitsinhi (Groves, 1983)

1983 *Cervus duvauceli ranjitsinhi* Groves. Guwahati, Assam.

A swampy-ground subspecies with spreading hooves and bare pasterns. Long nasals, short snout, slender from side to side but deep. Antlers short, thick, branching low down, with short anterior branch, somewhat compressed and tending to be palmate. Heavily built, with females rather small. Tail short; ears small, pointed, without much white hair inside. White median dorsal spots not prominent. Assam.

Genus *Rusa* Hamilton Smith, 1827

Regarded as a distinct genus, rather than a subgenus of *Cervus*, by Grubb (1990).

Rusa unicolor (Kerr, 1792). Sambar (Sambur)

Rusa unicolor unicolor (Kerr, 1792)

1792 *Cervus axis unicolor* Kerr. Ceylon (restricted by Hamilton Smith, 1827).
1792 *Cervus axis major* Kerr. Ceylon.
1799 *Cervus albicornis* Bechstein. Substitute for *major*.
1816 *Cervus niger* de Blainville. North India (restricted by Pocock).
1823 *Cervus aristotelis* G. Cuvier. Nepal.
1823 *Cervus leschenaulti* G. Cuvier. Coromandel.
1827 *Cervus hippelaphus* Hamilton Smith. Bengal. Not of Erxleben (1777) = *Cervus elaphus*.
1831 *Cervus jarai* Hodgson. Nepal.
1841 *Cervus heterocerus* Hodgson. Nepal.
1841 *Cervus nepalensis* Hodgson. Nepal.
1843 *Axis pennantii* Gray. India.

Antlers are relatively long, with short brow tines. The two terminal antler tines tend to form an equal fork, although this is variable; the relationship between their lengths is also variable, but the posteromedial tine is frequently the longer. From Sri Lanka and most of the mainland, except the far Northeast. Pocock (1943a) separated Sri Lankan and mainland sambar into different subspecies, an action described by Groves and Grubb (1987) as "based on scant evidence of a size difference" and, even were it fairly consistent, it would not be very convincing evidence for different subspecies, given the known environmental effects on body size among deer.

Rusa unicolor equina (G. Cuvier, 1823)

1823 *Cervus equinus* G. Cuvier. Sumatra.

Antlers are shorter, and brow tines are longer. The anterolateral tine always continues the line of the beam and is longer than the posteromedial tine. From the northeast of the Subcontinent; Pocock (1943a) mentions the Garo Hills.

Genus *Axis* Hamilton Smith, 1827

Axis axis (Erxleben, 1777). Chital or Spotted deer

1777 *Cervus axis* Erxleben. Banks of the Ganges.
1792 *Cervus axis maculates* Kerr. Banks of the Ganges.
1829 *Cervus axis* var. *indicus* G. Fischer.
1829 *Cervus axis* var. *ceylonensis* G. Fischer. Ceylon.
1831 *Cervus nudipalpebra* Ogilby. Banks of the Ganges.
1842 *Axis major* Hodgson.
1842 *Axis minor* Hodgson.
1905 *Cervus* (*Rusa*) *axis zeylanicus* Lydekker. Ceylon.

Pocock (1943b) did not admit the mainland and Sri Lankan populations as distinct subspecies.

Genus *Hyelaphus* Sundevall, 1846

This is usually placed as, at most, a subgenus of *Axis*, but Grubb (1990) regards it as a full genus, retaining the primitive antler plan of the *Cervus* group.

Hyelaphus porcinus (Zimmermann, 1780). Hog-deer

Hyelaphus porcinus porcinus (Zimmermann, 1780)
1780 *Cervus porcinus* Zimmermann, 1780. Bengal.
1883 *Cervus minor* Sclater. India. Not of Hodgson (1842).

From Sind and the Ganga north into Uttar Pradesh (erstwhile United Provinces), Nepal and northeastern India.

Hyelaphus porcinus oryzus (Kelaart, 1852)
1852 *Axis oryzus* Kelaart. Ceylon.

Pocock (1943b) separated the Sri Lankan subspecies on the basis of being smaller, with poorly developed antlers, without spots in the adult and with no marked seasonal change in colour. He admitted that the Sri Lankan population might actually be introduced (and the absence of hog-deer from southern India gives pause for thought). Whether there are any valid genetically based differences between them should be tested by future research.

FAMILY BOVIDAE

Genus *Bos* Linnaeus, 1758

Bos gaurus Hamilton Smith, 1827. Gaur or Indian bison

In historic times, gaur occurred in Sri Lanka (Knox 1681). The name *guavera* Kerr, 1792, which was based on Knox's description, was suppressed by the International Commission on Zoological Nomenclature (1985) in order to preserve the priority of the familiar name *gaurus*.

The subspecies as listed here, and the use of the name *laosiensis* in place of the more familiar *readei* for the Southeast Asian subspecies, are based on a revision in preparation by Grubb and Groves.

Bos gaurus gaurus Hamilton Smith, 1827
1827 *Bos gaurus* Hamilton Smith. Mainpat, Sarguja Tributary States, India.
1827 *Bos gour* Hardwicke. Mountainous district of Ramgurh and tableland of "Sirgoojas."
1837 *Bibos subhemachalus* Hodgson. Sal Forests, Nepal.
1837 *Bibos cavifrons* Hodgson. Substitute for *subhemachalus*.
1842 *Bibos concavifrons* Roulin. Substitute for *cavifrons*.
1846 *Bos gaur* Sundevall. Substitute for *gaurus*.
1851 *Bos asseel* Horsfield. No locality.

Indian gaur are rather smaller (mean skull length of males, 542 mm) than Southeast Asian gaur, but with relatively longer nasal bones (222 mm) and wider occiput. Northern Indian gaur do not differ in size from the from the peninsular ones, but have a markedly narrower span across the horns in males (mean values are 795 mm in northern India, 846 mm in the south). The range of this subspecies reaches Nepal and Sikkim.

Bos gaurus laosiensis (Heude, 1901)
1901 *Gauribos laosiensis* Heude. Camoun, in the mountains separating Laos and Tonkin.
1903 *Bos gaurus readei* Lydekker. Myitkyina, Burma.

Skulls from Assam resemble Southeast Asian gaur. The Southeast Asian subspecies is larger than Indian gaur (skull length averages 587 mm in male), with relatively short nasals (mean 228 mm); and the occiput is narrower. The horn tips are less turned in relative to the horn span.

Specimens from Bhutan and Chittagong are intermediate between the two subspecies.

Bos javanicus d'Alton (1823). Banteng
1898 *Bos sondaicus birmanicus* Lydekker. Burma.

There have been constant reports of banteng in Manipur, but there is as yet no confirmation.

Bos mutus (Przewalski, 1883). Wild yak
1883 *Poephagus mutus* Przewalski. Western Nan Shan, Ganssu.

Yak enter Indian territory in Ladakh.

Bubalus arnee (Kerr, 1792). Wild buffalo or Arna

The subspecies of the Subcontinent, and their characters, are after Groves (1996). The question of whether the Sri Lankan wild buffaloes are wild or feral is unresolved.

Bubalus arnee arnee (Kerr, 1792)
1792 *Bos arnee* Kerr. Restricted to Kuch Behar by Harper (1940).
1807 *Bos arni* Blumenbach. Mountains of north Hindustan.
1852 *Bubalus arna* var. *macrocerus* Gray. After a *nomen nudum* of Hodgson (1841). "India" (probably Nepal).
1912 *Bubalus bubalus septentrionalis* Matschie. Kuckri-Muckri, an island in the Bay of Bengal, off the Sunderbans.

Formerly occurred from the Sunderbans into Nepal, Madhya Pradesh and Andhra Pradesh; still occurs in Raipur and Bastar districts (Madhya Pradesh) and Kosi Tappu Reserve (Nepal), but in very small numbers, probably less than 200. Skull length usually under 570 mm, horn span under 1,200 mm. Black, with contrasting white limbs below knees and hocks, and white muzzle; tail reaches down to hocks.

Bubalus arnee fulvus (Blanford, 1891)
1891 *Bos arnee fulvus* Blanford. Mishmi Hills.

Brahmaputra Valley, formerly from Koch Behar to Mishmi Hills and south to Chittagong Hills; still occurs sporadically along the Brahmaputra and in Manas (Choudhury 1997). Larger, skull length usually over 570 mm, horn span over 1,100 mm. Grey or brownish grey, and less contrastingly white on limbs; tail falls short of hocks.

Genus *Boselaphus* de Blainville, 1816

Boselaphus tragocamelus (Pallas, 1766). Nilgai
1766 *Antilope tragocamelus* Pallas. Plains of peninsular India.
1777 *Antilope albipes* Erxleben. India.
1777 *Antilope picta* Pallas. India.
1827 *Damalis risia* Hamilton Smith. Substitute for *picta.*
1837 *Tragelaphus hippelaphus* Ogilby. Substitute for *picta.*
1846 *Portax tragelaphus* Sundevall. Error for *tragocamelus.*

There is very little geographic variation in male nilgai skulls, from localities as far apart as Gir, Rajasthan, Bhopal, Kanpur and Patna. A skull from Bengal, however, is overall one of the smallest, with the shortest horns, but the widest in bizygomatic breadth [157 mm, cf. 131-148 mm (n=20) from other localities].

Genus *Tetracerus* Leach, 1825

Tetracerus quadricornis (de Blainville, 1816). Chowsingha or Four-horned antelope

Unlike the nilgai, the chowsingha has well-marked geographic variation, and we can distinguish three subspecies. The metric differences are given in Table 1.

Tetracerus quadricornis quadricornis (de Blainville, 1816)
1816 *Cerophorus (Cervicapra) quadricornis* de Blainville. Plains of peninsular India.
1825 *Antilope chickara* Hardwicke. Bengal, Bihar and Orissa.

1828 *Antilope tetracornis* Hodgson. No locality.

A relatively large form with narrow nasal bones. Four long horns. Colour yellow-fawn above, creamy or creamy-fawn below, this tone often confined to midline; forelimbs markedly blackened down anterior surface; median dorsal region darker than rest of upperside; tail long, with bushy white tip. Nose diffusely darker. I have seen specimens from Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, Bihar, Bengal, the eastern Godavari in Andhra Pradesh, and Sandur in Karnataka.

Tetracerus quadricornis iodes Hodgson, 1847

1847 *Tetracerus iodes* Hodgson. Sal Forests of sub-Himalayan region.

1847 *Tetracerus paccerois* Hodgson. Same locality.

Similar in size, but with wider nasals; horns smaller. Colour variably fawn above, light fawn below, this tone often confined to a very narrow midline streak; foreleg with at most a vague, dark brown line, which may be interrupted at knee; median dorsal region not darkened. Nose diffusely darker. The four skins and skulls I have seen are from Nepal (3) and Champa (1).

Tetracerus quadricornis subquadricornis (Gray, 1843)

1839 *Antilope sub-4-cornutus* Elliot. Southern Mahratta country.

1843 *Tetracerus subquadricornis* Gray.

1847 *Teracerus subquadricornutus* Hodgson. Emendation of *sub-4-cornutus*.

Smaller in size, with very broad nasals; only a single pair of horns, which are rather long. Colour varying from red-fawn to more olive above; underside whitish in midline, pale yellow laterally; foreleg line very vague or absent; median dorsal region slightly darkened; midline of nose may be sharply darker; tail short. The four male and two female skulls and 9 skins are from Palkonda Hills, Madras(= Chennai), Dharwar and Kuckanalla.

Genus *Procapra* Hodgson, 1846

Procapra picticaudata Hodgson, 1846. Tibetan gazelle or Goa

1846 *Procapra picticaudata* Hodgson. Hundes, Tibet.

Like yak, goa enter the Indian region in Ladakh. The species is monotypic.

Genus *Gazella* de Blainville, 1816

Gazella bennettii (Sykes, 1831). Chinkara or Indian gazelle

Groves (1993b) revised this species in Iran, and the accumulation of specimens from India now enables me to do the same for the species in the Subcontinent, including the description of a new subspecies. Apart from the three described subspecies, I have good-sized samples from two other regions, the Salt Range (including Punjab and Haryana) and the Ganga Valley, and I here describe the first of these as a new subspecies. Their measurements are given in Table 2.

Gazella bennettii bennettii (Sykes, 1831)

1831 *Antilope bennettii* Sykes. Deccan.

1843 *Antilope hazenna* I. Geoffroy St. Hilaire. Malwa.

Table 1: Differences in measurements of *Tetracerus quadricornis* subspecies

Measurements in mm ±SE (n)	*quadricornis*	*iodes*	*subquadricornis*
Skull length (male)	192.9 ±5.47 (11)	191.0 (1)	187.0 ±3.00 (3)
Nasal breadth (male)	17.2 ±1.38 (17)	18.7 ±2.52 (3)	19.7 ±1.15 (3)
Number of horns	4	4	2
Posterior horn length	90.7 ±10.61 (23)	73.5 ±4.73 (4)	83.5 ±13.18 (4)
Anterior horn length	48.6 ±3.78 (7) Rajasthan 31.7 ±11.31 (11) elsewhere	20.7 ±5.69 (3)	-

Table 2: Comparative measurements of *Gazella* spp.

Measurements in mm ±SE (n)	*fuscifrons*	*salinarum*	*christyi*	Ganga Valley	Rajasthan	*bennettii*
Males:						
Horn length	247.2 ±23.9 (11)	283.5 ±16.1 (16)	284.3 ±19.1 (26)	256.1 ±33.2 (18)	269.8 ±25.4 (12)	253.0 ±12.7 (7)
Horn span	119.5 ±22.8 (11)	145.4 ±36.1 (14)	139.6 ±22.6 (26)	132.7 ±31.1 (17)	140.3 ±22.8 (12)	103.8 ±15.7 (6)
Bases of cores	62.1 ±4.59 (10)	66.1 ±2.75 (17)	64.5 ±2.34 (26)	64.6 ±3.88 (19)	62.8 ±1.63 (13)	62.6 ±5.32 (8)
Nasal breadth	24.0 ±1.22 (8)	24.3 ±1.28 (8)	22.1 ±1.93 (11)	22.5 ±1.69 (11)	22.8 ±0.92 (10)	21.0 ±2.00 (3)
Nasal length	51.3 ±4.62 (8)	56.8 ±3.28 (8)	54.1 ±4.85 (11)	55.4 ±5.36 (10)	52.2 ±4.46 (9)	50.7 ±4.04 (3)
Skull length	184.4 ±4.47 (7)	198.0 ±5.80 (6)	191.1 ±2.61 (7)	182.9 ±7.95 (7)	186.0 ±3.70 (8)	171.0 (2)
Biorbital breadth	83.8 ±2.18 (9)	87.2 ±1.91 (16)	85.5 ±2.14 (25)	84.9 ±3.77 (17)	84.8 ±2.45 (13)	80.8 ±1.94 (6)
Preorbital length	94.1 ±3.64 (8)	99.8 ±3.77 (8)	97.0 ±3.02 (8)	94.0 ±6.71 (9)	94.1 ±2.59 (8)	87.0 (2)
Toothrow length	56.9 ±1.27 (9)	57.6 ±2.84 (12)	56.0 ±3.57 (12)	55.9 ±3.09 (14)	57.0 ±2.52 (12)	54.8 ±2.59 (5)
Females:						
Horn length	175.4 ±38.4 (5)	136.0 ±29.5 (3)	118.0 ±23.5 (3)	119.2 ±21.2 (5)	130.5 ±12.0 (4)	110.0 (2)
Horn span	77.5 ±13.2 (4)	58 (1)	91 (1)	67.0 (2)	69.5 (2)	57 (1)
Bases of cores	52.4 ±2.92 (7)	51.7 ±1.53 (3)	50.4 ±1.34(5)	51.4 ±0.98 (7)	50.0 ±1.58 (5	50.8 ±0.76 (3)
Nasal breadth	22.8 ±1.72 (6)	22.0 (2)	21 (1)	21.4 ±1.52 (5)	21.5 ±1.66 (5)	20.0 (2)
Nasal length	47.3 ±5.54 (6)	55.5 (2)	46.0 ±7.81 (3)	48.8 ±4.44 (5)	52.0 ±3.37 (4)	53.7 ±6.35 (3)
Skull length	179.4 ±5.37 (5)	191.5 (2)	184.0 (2)	181.0 ±7.71 (5)	182.8 ±3.49 (5)	172 (1)
Biorbital breadth	80.9 ±3.20 (6)	82.7 ±3.21 (4)	81.0 ±2.00 (4)	80.9 ±2.12 (7)	82.0 ±1.22 (5)	78.7 ±1.15 (3)
Preorbital length	92.7 ±4.79 (5)	102.5 (2)	95.5 (2)	93.3 ±4.55 (6)	95.6 ±3.36 (5)	89 (1)
Toothrow length	55.7 ±2.06 (7)	58.7 ±2.52 (3)	56.0 ±4.55 (4)	54.7 ±3.59 (7)	56.6 ±3.05 (5)	56.7 ±2.08 (3)

From Ganga Valley and its vicinity (Muttra, Gwalior, Jhansi, Etawah, Hamirpur, Allahabad, Rewa, Jabalpur, Nimar, Asirgarh, Palamau, Jagodih, Hazaribagh) and the Deccan (Hyderabad, Haturna, Indore, Bhopal, Khandesh). 14 skins, 3 head-skins, 41 full or partial skulls (including frontlets and horns). Head, neck, limbs and most of flanks dull reddish brown; median dorsal region and lower flanks (abutting the white underparts) are abruptly darker, tawny. Winter coat is distinctly longer than summer, but the colour does not differ. The Ganga Valley gazelles are of much larger skull size, with more widely spreading horns (but of equal size), than those of the Deccan, and it may be appropriate to separate them into two subspecies if further material from the Deccan confirms these trends; but the pelage characters are identical.

Gazella bennettii christyi Blyth, 1842
1842 *Gazella christii* Blyth. Thar Desert.

From Kutch and Saurashtra, as far east as Ahmedabad. 12 skins, 39 full or partial skulls (including frontlets and horns). Most skins are very pale, almost silvery drab brown with only very restricted median dorsal and lower flank zones being slightly darker than the rest of the body; a few are slightly richer, with more contrast. Winter coat hardly longer than summer. More sexually dimorphic than *Gazella bennettii bennettii*: male, but not female, is larger and longer-horned.

Gazella bennettii fuscifrons Blanford, 1873
1873 *Gazella fuscifrons* Blanford. Jalk, southeastern Iran.

From Baluchistan (Iran and Pakistan) to Sind and Rajasthan (Bikaner, Jodhpur, Jaisalmer). 16 skins, 36 full or partial skulls (including frontlets and horns). Colour in winter dark grayish sandy, often with a distinct brown band edging the white of the underparts but without much median dorsal darkening; in summer, brownish bay-fawn. Coat with very long hair in winter. Size as in Ganga Valley population of *G.b. bennettii*, but with shorter, broader nasals, especially in males; males have shorter, more upright horns, but females have longer horns than any other subspecies in the Subcontinent. The cranial and horn metrics of Rajasthan specimens are nearly identical to those from Baluchistan and Sind, and pelage characters are the same.

Gazella bennettii salinarum s.s. nov.

Type: BM(NH) 25.10.3.5, skin and skull of adult female from Ara, Salt Range, 700 m above msl. Specimens seen: 3 skins, 1 head-skin, 17 male and 3 female skulls. Haripur, Pind Didan Khan, Faridkot (skins and skulls), "Punjab" (skull and head-skin), Barra Jandhi, Sirsa, Gurgaon, Rohtak, Hissar (skulls only). British Museum (Natural History), Museum Alexander Koenig (Bonn), Zoological Survey of India (Kolkata), Royal Scottish Museum (Edinburgh).

From the Salt Range east as far as Delhi.

Skin rich tobacco-brown, with no contrasting zone on the midback, but a contrasting flank band. The largest subspecies all round, in both sexes, with especially long nasals. Skull length in males is from 190 to 203 mm (only one specimen under 193); that of *G.b. christyi,* the next largest subspecies, is 187 to 195 mm (only one specimen above 193). Skull length in the two females is 186 and 197 mm; in both the two females of *G.b. christyi* it is 184 mm.

Gazella subgutturosa (Güldenstaedt, 1780). Goitred gazelle
1780 *Antilope subgutturosa* Güldenstaedt. Tbilisi, Georgia.

I have seen a herd from Pakistan in the private collection of Sheikhs Khalid and Hassan al-Thani at Al Wabra, near Doha, Qatar. They do not appear distinguishable in external characters from the nominotypical subspecies of the Iranian plateau, but this must remain a subjective judgement until specimens can be examined.

Genus *Antilope* Linnaeus, 1758

Antilope cervicapra (Linnaeus, 1758). Blackbuck

On geographic variation in this species, see Groves (1982). Dr. E.C. Mungall (pers. comm.) is examining the status of blackbuck from Point Calimere, which may represent a further subspecies, as yet undescribed.

Antilope cervicapra cervicapra (Linnaeus, 1758)
1758 *Capra cervicapra* Linnaeus. Inland of Trivandrum, restricted by Zukowsky, 1927).
1776 *Antilope rupicapra* Müller. Bengal.
1830 *Antilope bilineata* Gray. Bengal.
1843 *Cervicapra bezoartica* Gray. India.
1927 *Antilope hagenbecki* Zukowsky. Bengal.

From approximately east and south of the Delhi region, south to Chennai (earlier Madras) and Karnataka (Rannebenur) and to Vallanadu Reserve Forests in Tirunelveli district, and east to Bihar and Bengal. Smaller, with short fine hair; the dark colour runs all down the limbs to the hoofs, and the white eye-ring is narrowed above the eye. Horns are relatively short, not very divergent, and have a relatively open spiral.

Antilope cervicapra rajputanae Zukowsky, 1927
1927 *Antilope rajputanae* Zukowsky. Bahawalpur, borders of Rajasthan and Panjab.
1928 *Antilope centralis* Zukowsky. Gwalior.

From west of the Delhi region, to Saurashtra and Vadodara, Amritsar and into Pakistan. Larger, with longer, roughened pelage; the male in the breeding season has a grey sheen; the shanks are largely white, with little or no extension of the dark colour from the upper limb segments; the white eye-ring is broad all around the eye. Horns tend to be longer, more divergent and more closely spiralled.

Genus *Pantholops* Hodgson, 1834

Pantholops hodgsonii (Abel, 1826). Chiru
1826 *Antelope hodgsonii* Abel. Tingri Maidan, Arun Valley, Kooti Pass, Tibet.
1827 *Antilope kemas* Hamilton Smith. Central Asia.
1827 *Antilope chiru* Lesson. Nepal.

This species enters the Indian region in Ladakh; whether they have ever genuinely occurred in Nepal is unclear.

Genus *Ovis* Linnaeus, 1758

Ovis vignei Blyth, 1841. Urial

Geographic variation in this species is after Schaller (1977).

Ovis vignei vignei Blyth, 1841. Ladakh urial
1841 *Ovis vignei* Blyth. Astor, Kashmir.
1854 *Ovis montana* Cunningham. Ladakh.

From Ladakh; in Zanskar, it is sympatric with *O. ammon*. Horns of male thick, 230-260 mm in circumference, rise more steeply from the head and more corrugated than that of other urials, and tend to be supracervical (heteronymous), but sickle-shaped and homonymous occasionally occur. Colour brownish or greyish, with a grey saddle, occasionally with a dark line in front.

Ovis vignei punjabiensis Lydekker, 1913. Punjab urial
1913 *Ovis vignei punjabiensis* Lydekker. Salt Range, Punjab.

From the Salt and Kala Chitta Ranges, between the Indus and Jhelum rivers. Horns of male more slender (190-240 mm in circumference), sickle-shaped, with either tighter or looser curl. More reddish, with a two-coloured saddle patch (but this may be white only, or absent). The ruff, usually black in all urials, is occasionally white in this subspecies.

Ovis vignei cycloceros Hutton, 1842. Afghan urial
1842 *Ovis cycloceros* Hutton. Hazara Hills, near Kandahar, Afghanistan.
1877 *Ovis blanfordi* Hume. Hills above Bolan Pass, near Kelat, Baluchistan.

From Pakistan, west of the Indus, into Afghanistan. Horns of male 210-270 mm in circumference, usually homonymous. Reddish-buff to yellowish or light brown, with a small black saddle spot.

Ovis ammon Linnaeus, 1758. Argali

Geographic variation in this species follows Geist (1991).

Ovis ammon hodgsonii Blyth, 1841. Tibetan argali

1841 *Ovis hodgsonii* Blyth. Tibet, on Nepal frontier.
1841 *Ovis ammonoides* Hodgson. Himalayan region.
1852 *Caprovis bambhera* Gray. Nepal.
1874 *Ovis brookei* Ward. Ladakh.

In the Subcontinent extends into Ladakh, Sikkim and, formerly, Nepal. In mature rams, the long-haired, light-coloured ruff is sharply set off from the dark shoulders; rump patch distinctly set off dorsally, surrounds the tail; dark partial flank band, separating light belly from dark body; dark stripe from chest to hooves contrasts with light colour of rest of limbs. Face wholly dark in young, with light rostrum in old males. Horns of adult males have less developed combat edge (on external angle), less everted; of adult females long, thick, angular, usually about 450 mm long, occasionally up to 600 mm. Tail tiny, up to about 83 mm including hair, 58 mm without.

Ovis ammon polii Blyth, 1841. Pamir argali or Marco Polo's sheep

1841 *Ovis polii* Blyth. Near sources of Syr Darya, Pamir.

In the Subcontinent, extends to Hunza, Pakistan. Neck ruff of mature rams shorter, blends gradually with body tone; no sharp contrasts of pelage, grading between dark upper parts and white underparts and limbs; white of rump patch usually not sharply set off above, and continuous with an extensive white zone on thighs, hindlegs, underside and forelegs; flank stripe narrow, only slightly darker than body, extends along flank and tops of limbs. Face light. Horns of adult males with well-developed combat edge, relatively thin, widely flaring, arise at a shallower angle; of ewes, relatively short and thin. Tail longer, 120-150 mm long including hair, 100 mm without.

Genus *Pseudois* Hodgson, 1846

Pseudois nayaur (Hodgson, 1833). Bharal or Blue sheep

1833 *Ovis nayaur* Hodgson. Tibetan frontier of Nepal.
1835 *Ovis nahoor* Hodgson. Alternative name.
1841 *Ovis burrhel* Blyth. Boorendo Pass.

Extends from the Karakoram eastward through Ladakh all along the Himalayan slopes from 3,500 to 5,500 m above msl (Schaller 1977).

Genus *Capra* Linnaeus, 1758

Capra sibirica (Pallas, 1776). Siberian ibex

Capra sibirica sakeen Blyth, 1842

1842 *Capra sakeen* Blyth. Tibetan slopes of Himalayas.
1844 *Aegoceros skyn* Wagner. Baltistan, Kashmir.
1886 *Capra dauvergnii* Sterndale. Hills north of Kishenganga river, Kashmir.
1900 *Capra sibirica wardi* Lydekker. Braldu, Baltistan, near Baltoro Glacier.
1906 *Capra sibirica pedri* Lorenz. Gilgit, Kashmir.
1911 *Capra sibirica filippii* Camerano. Lahul.

In the region, ibex are found on high, rocky cliffs, seldom below 3,000 m, from the Hindu Kush east only to the Sutlej river. Kashmir ibex resemble those from the Tianshan (*Capra sibirica alaiana*), and differ from those from the Altai (*C.s. sibirica*), in their large size and long nasal bones, and the large white saddle on the back, but differ in their shorter horns, and the failure of the saddle to extend to the haunches.

Capra aegagrus Erxleben, 1777. Bezoar goat

Capra aegagrus blythi Hume, 1875.

1875 *Capra blythi* Hume. Sind.

1913 *Capra falconeri chialtanensis* Lydekker. Chiltan Range, near Quetta, Baluchistan.

Bezoar goats occur on the low desert ranges of Pakistan west of the Indus, both sympatric with markhor (as on the Murdar Range, near Quetta, and in the Gadabar Ghar Range, east of Loralai) and separately (south of about 30° N). On some of these ranges, along with the common scimitar-horned form, occur screw-horned *Capra*, called Chiltan goats by Schaller and Khan (1975). These were originally described as a subspecies of markhor by Lydekker (*Capra falconeri chialtanensis*), but their status has been queried and discussed by both Schaller and Khan (1975) and Roberts (1977).

According to Schaller and Khan (1975; see also Schaller 1977), Chiltan goats are found intermingled in the same herds as scimitar-horned goats in the Zahri, Koh-i-Maran and Dilband-Moro ranges and districts; as the only *Capra* on the Chiltan Range; and on the Murdar Range, where goat and markhor are sympatric.

Schaller and Khan (1975) consider that Chiltan goats are a polymorphic variant of *Capra aegagrus*. They note that the horns lack the markhor's posterior keel, and the cross-section is oval like a scimitar-horned bezoar's horn; there is no neck ruff; and the pelage resembles a bezoar. Where it coexists with scimitar-horned goats, the two are found intermingled in the same herds.

For Roberts (1977), however, the Chiltan goat is a hybrid between bezoar and markhor. The female resembles markhor, being reddish-grey with a dorsal stripe and creamy legs with a pattern on the front; but Roberts admits that bezoar can be reddish-grey as well, although they have a dark face pattern and the legs are greyer, less creamy. The male, he agrees, resembles bezoar more, becoming more and more grey-white with age, and some have a black chest and shoulder-stripe like the bezoar. He says that there have been some local extinctions of bezoar or markhor, and implies that early in the 20th century the distribution of Chiltan goats encompassed all the ranges where bezoar and markhor were sympatric.

The type of *chialtanensis* is a frontlet with horns, but there is also a nearly complete skull of a Chiltan goat in the Natural History Museum (London), BM 67.795. This is as big as a markhor, and bigger than any bezoar, but has big teeth like a bezoar (Table 3). In my opinion, the Chiltan goat is most likely to be a hybrid.

Table 3: Comparison of Chiltan goat with markhor and with scimitar-horned bezoar

	Baluchi markhor	Chiltan goat	Largest bezoar
Biorbital breadth	145 mm	146	144 (usually 140)
Nasal length	89	88	82
Maxillary toothrow	77	84	82

Capra falconeri (Wagner, 1839). Markhor

Geographic variation after Schaller and Khan (1975).

Capra falconeri falconeri (Wagner, 1839)

1839 *Aegoceros (Capra) falconeri* Wagner. Kashmir (restricted to Astor by Lydekker, 1913).

1898 *Capra falconeri cashmiriensis* Lydekker. Pir Panjal Range, Kashmir.

1958 *Capra falconeri chitralensis* Cobb. Chitral.

1958 *Capra falconeri gilgitensis* Cobb. Gilgit watershed. *Nomen nudum.*

From eastern Afghanistan east to Kashmir. Horns are more curved, wider across the tips; size is larger, and the coat is longer and silkier, with a well-developed neck ruff. The "Kashmir" horn type, moderately divergent and with 2 or 3 twists, occurs in Afghanistan, Chitral, Dir, and Swat, and again in Shamsberi, Kaj-i-Nag and Pir Panjal; the more flaring, less twisted (1.5 turns) "Astor" type predominates in intervening localities.

Capra falconeri megaceros Hutton, 1842

1842 *Capra megaceros* Hutton. Kandahar, Afghanistan.
1875 *Capra jerdoni* Hume. Suleiman Range, Punjab, Pakistan.

From the northern hill ranges of Pakistan. Horns are less curved (more closely corkscrewed, less divergent; size is smaller, and the pelage is shorter, with (usually) no distinct ruff. Two horn types, the more open-spiralled Kabul type, and the more corkscrew Sulaiman type, occur together widely.

Genus *Hemitragus* Hodgson, 1841

Hemitragus jemlahicus (Hamilton Smith, 1826). Himalayan tahr

1826 *Capra jemlahica* Hamilton Smith. Jemla Hills, Nepal.
1833 *Capra jharal* Hodgson. Nepal.
1836 *Capra quadrimammis* Hodgson. Nepal.
1845 *Capra tubericornis* Schinz. Substitute for *jemlahica*.
1944 *Hemitragus jemlahicus schaeferi* Pohle. 10 km southwest of Chuntang, Sikkim.

The range, according to Schaller (1977), extends from about 40 km west of Banihal Pass, in the Pir Panjal, east into Bhutan, in cliff country where they migrate seasonally between forest and alpine zones.

Hemitragus hylocrius (Ogilby, 1838). Nilgiri tahr

1838 *Kemas hylocrius* Ogilby. Nilgiri Hills.
1842 *Capra (Ibex) warryato* Gray. Nilgiri Hills.

Found in the highlands of the Tamil Nadu/Kerala borderlands, presently surviving mainly in the Nilgiri Hills, High Range and Highwavy Mountains; in rolling country at 1,200 to 2,600 m above msl (Schaller 1977).

Genus *Capricornis* Ogilby, 1837

The taxonomy of this genus follows Grubb and Groves (in prep.). Himalayan serow are sharply distinct from those in China or Southeast Asia, and there is no merit in keeping them in the same species.

Capricornis thar (Hodgson, 1831). Himalayan serow

1831 *Antilope thar* Hodgson. Nepal Himalaya.
1832 *Antilope bubalina* Hodgson. Nepal.
1842 *Nemorhaedus* or *Kemas proclivus* or *thar* Hodgson. *Nomen nudum.*
1908 *Capricornis sumatraensis humei* Pocock. Kashmir.
1908 *Capricornis sumatraensis rodoni* Pocock. Chamba, Panjab.
1908 *Capricornis sumatraensis jamrachi* Pocock. Kalimpong, near Darjiling.

From Kashmir, almost at the Afghanistan border, east as far as the Lushai Hills, Assam. This species is black, with a buffy tone as the black tips wear off and reveal the lighter hair bases; a long mane, mixed black and white; below, sharply cream-buff; broadly white over nose, or only on lip margins; white extends backwards along jawlines in a 'V' shape, or interramal region completely white, or occasionally white tones are nearly absent; legs creamy-white from below knees and hocks.

An erythristic population (subspecies or separate species?) occurs in the Garo, Mishmi and Naga Hills. This is close to *C. thar* in its fairly long pelage, white hair-bases, and black and white mane; it is different from *Capricornis rubidus* of northern Burma, which differs in its very short pelage, the black (not white or buffy) hair-bases, the black dorsal stripe, and the very short dark red mane.

Genus *Nemorhaedus* Hamilton Smith, 1827

As in *Capricornis*, the taxonomy of this genus follows Grubb and Groves (in prep.).

Nemorhaedus goral (Hardwicke, 1825). Himalayan goral

Nemorhaedus goral goral (Hardwicke, 1825). Brown goral

1825 *Antilope goral* Hardwicke. Kathmandu.
1827 *Antilope duvaucelii* Hamilton Smith, 1827.
1908 *Naemorhedus hodgsoni* Pocock. Sikkim.

From Bhutan west to about Nainital. Medium brown with black hair tips, giving a hare-like effect; or slightly greyer, to grey-brown; or pale or dark fawn; legs browner, to very bright tan, or white on forelegs only. Underside paler grey. Throat and chin variably white, may be interrupted under jaw; lips white. Dorsal stripe usually weak, may fade behind withers.

Nemorhaedus goral bedfordi (Lydekker, 1905). Grey goral

1905 *Urotragus bedfordi* Lydekker. Dharmsala.

From Chamba and Kulu, west into Kashmir. Grey to grey-brown to yellow-grey; legs lighter, yellower, with dark brown line down front, fading on pasterns. Underside off-white. Throat and chin creamy the whole way. Merest trace (if that) of dorsal stripe.

Genus *Budorcas* Hodgson, 1850

Takin of India and Bhutan differ from those of China in their smaller horns and in the brown rather than golden colour, except for a lighter, yellow-toned saddle. They become blacker with age, this colour developing earliest on the underside, haunches and limbs.

Budorcas taxicolor Hodgson, 1850. Takin

Budorcas taxicolor taxicolor Hodgson, 1850

1850 *Budorcas taxicolor* Hodgson. Mishmi Hills.

Known from the Mishmi Hills (extending into Chinese and Burmese territory). Males much larger than females (biorbital breadth over 190 mm in males, less than 176 in females); teeth relatively small, maxillary toothrow length 114-122 mm; horns of males very large, their span 341-411 mm.

Budorcas taxicolor whitei Lydekker, 1907

1907 *Budorcas taxicolor* whitei Lydekker. Bhutan.

From Sikkim and Bhutan. Males as small as females (biorbital breadth 166-182 mm in both sexes); maxillary toothrow length 120-124 mm; horns of males smaller, their span 297-357 mm.

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DISAPPEARANCE OF THE WHITE-WINGED DUCK *CAIRINA SCUTULATA* FROM THE PABLAKHALI WILDLIFE SANCTUARY: A SAGA OF LARGE-SCALE DESTRUCTION OF MIXED EVERGREEN FOREST IN BANGLADESH

(*With one text-figure and two plates*)

MOHAMMAD ALI REZA KHAN[1]

Key words: Bangladesh, Biodiversity Bureau, clear-felling, *jhum* cultivation, monoculture, Kaptai Lake, Pablakhali, Rangamati, tribal insurgency, white-winged duck

Bangladesh used to be a country with rich fauna and flora. During the rule of the British, largely after the 1850s, the first commercial exploitation of natural resources *vis-à-vis* the forests was introduced. This included 'clear-felling' of trees in the Sal Forests of central and northwestern parts, and Semi-evergreen or Mixed Evergreen Forests of north and eastern parts of present Bangladesh. The same tradition was carried forward by the Pakistani authorities who ruled the then East Pakistan (now Bangladesh) from 1947 to 1971. After the independence of Bangladesh, in December 1971, the forest officials kept following their predecessors in destroying forests. Forest destruction became more rampant as the new government had few environmental policy decisions. The situation was further aggravated by lumber poaching, land grabbing, and settling people in the reserved forest areas leading to tribal insurgency. All this ultimately brought an end to the existence of virgin Mixed Evergreen Forest in the northeastern parts of Bangladesh. The white-winged duck *Cairina scutulata* is a victim of this process. This paper examines the process of destruction of the forests and suggests measures to save the remaining habitats of the still surviving biodiversity through the creation of a Wildlife/Biodiversity Bureau separating it completely from the Forest Department that traditionally and wrongly acted against the interests of indigenous wildlife in the past.

INTRODUCTION

White-winged duck or white-winged wood duck *Cairina scutulata* used to be present in a section of the Mixed Evergreen Forest in the Chittagong Hill Tracts (CHT) District of Bangladesh bordering the Indian State of Mizoram (Husain 1977, 1985, Husain and Haque 1982, Khan 1981, 1983, 1986). These reports were based on observations made prior to 1980. The population was estimated to be 25 birds at that time.

Bangladesh has an area of roughly 147, 570 sq. km and lies between 20° 34' to 26° 38' N and 88° 01' to 92° 41' E. It is bounded on the west, north and east by India, with a small portion of the southeast corner bordering with Myanmar (Fig. 1). The Bay of Bengal covers the entire southern border. Bangladesh occurs at the confluence of three mighty rivers, the Padma (Ganga), the Brahmaputra and the Meghna, forming one of the largest deltas of the world. It used to have three distinct forest types: Moist Deciduous or Sal, Mixed or Semi-evergreen, and the Mangrove Forest in the Sundarbans (Khan 1982).

Around 1970, the country had roughly 15% land area under forests. However, following independence, in December 1971, there was large-scale systematic removal of forests by the government Forest Department whose main aim was, and possibly still is, to provide revenue to the government exchequer through cutting and selling of forest wood. This was followed by illicit logging, poaching for firewood and illegal conversion of forested land into agricultural fields and human habitations, as well as road building

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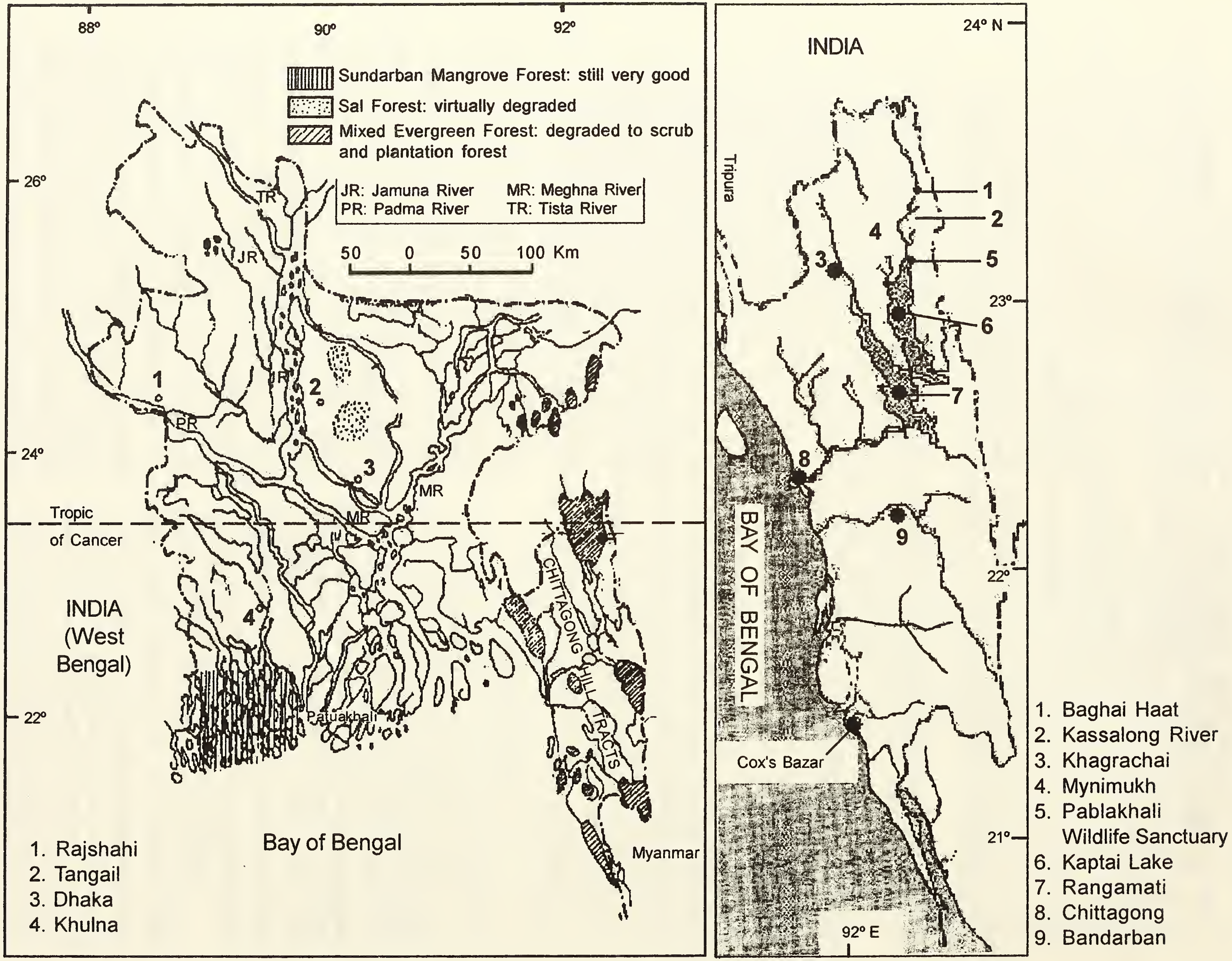
88°
90°
92°
26°
24°
22°
Sundarban Mangrove Forest: still very good
Sal Forest: virtually degraded
Mixed Evergreen Forest: degraded to scrub and plantation forest
JR: Jamuna River
PR: Padma River
MR: Meghna River
TR: Tista River
50 0 50 100 Km
TR
JR
PR
MR
1
2
3
4
Tropic of Cancer
INDIA (West Bengal)
Patuakhali
CHITTAGONG HILL TRACTS
Myanmar
Bay of Bengal
1. Rajshahi
2. Tangail
3. Dhaka
4. Khulna
INDIA
Tripura
24° N
23°
22°
21°
92° E
BAY OF BENGAL
Cox's Bazar
1
2
3
4
5
6
7
8
9
1. Baghai Haat
2. Kassalong River
3. Khagrachai
4. Mynimukh
5. Pablakhali Wildlife Sanctuary
6. Kaptai Lake
7. Rangamati
8. Chittagong
9. Bandarban

Fig. 1: Map of Bangladesh showing forest types (left) and Chittagong Hill Tracts (enlarged; right)

and industrial development. There was, and still is, large-scale conversion of forested land into monocultures of commercially viable plant species such as *Tectona grandis*, *Dipterocarpus turbinatus*, *Syzygium grandis*, *Gmelina arborea*, *Hevea brazilensis*, *Hopea odorata*, *Michelia champaca* and *Mesua ferrea*.

Today there is virtually no virgin Sal or Mixed Evergreen Forest in the country other than the Sundarbans Mangrove Forest. In a recent report, IUCN Bangladesh (2000) said that though a current forest inventory is unavailable, it is estimated that the forest cover has been reduced by more than 50% since the 1970s. Estimates in 1990 revealed that Bangladesh has less than 0.02 ha of forest per capita — one of the lowest forest to population ratios in the world. Presently, less than 8% of the country is under forest cover — that too is neither natural nor virgin (Plate 1, Fig. 1).

Bangladesh had its best Mixed Evergreen Forest in the CHT District on the banks of the hill river, Kassalong (Fig. 1). The Kaptai Dam was constructed here to generate hydroelectric power in the 1960s, as a result of which a large portion of the valley forest was inundated. Even then, it had a viable forest with an immense variety of wildlife almost up to 1980, as described in old District Gazetteers and Working Plans of the Forest Department.

After 1980, bloody insurgency reigned, continued up to January 1998 and subsided by February 10 the same year, when tribal insurgents surrendered their arms as per a peace treaty that they signed with the Bangladesh Government. Tribals objected to the settlement of plains-dwelling Bengali people in the hilly areas of the northeast.

Chittagong Hill Tracts District has been bifurcated into Bandarban, Khagrachari and Rangamati Hill Districts in the recent past.

White-winged duck (WWD) used to be present in good numbers in the Pablakhali Wildlife Sanctuary at the heart of Kassalong Valley Forest under the CHT North Forest Division. It is a threatened species as per BIRDS TO WATCH-2 of BirdLife International (former ICBP - International Council for Bird Preservation) and the IUCN (International Union for Conservation of Nature and Natural Resources) Red Data Book. Also it is in Schedule I of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) (Green 1993) and Schedule III of the Bangladesh Wildlife Preservation Act 1973. Bangladesh is a party to the CITES. That means this species cannot be traded, trapped or killed, nationally or internationally.

HABITAT SURVEY

I conducted a field survey of the known habitats of the WWD from August 15 to 21, 2000, when a wildlife researcher from Dhaka helped me in my fieldwork. I had also visited the area from February18 to 22, soon after the tribal insurgents from the area surrendered their arms to the Bangladesh Government on February 10, 1998. From Rangamati town, that houses both the district as well Forest Division headquarters, we went to Mynimukh (22° 59.226' N; 92° 12.226' E) about 60 km upstream northwards, along the Kassalong river by a motor launch. From there we travelled to Gulshakhali and then to Rangi Para (22° 59.304' N; 92° 14.531' E) by motorboat. Mostly settlers live in these two spots. We met just two tribal Chakmas here, but were able to talk to a schoolteacher and a few local woodcutters. Later on, we moved to Pablakhali Wildlife Sanctuary (Fig. 1), about 10 km northeast of Mynimukh.

The Sanctuary's office is at a village called Amtali, which used to be a small outpost 20 years ago with only a tiny grocery shop. Everyone in the area used kerosene oil lanterns. Now it is a bustling town with nearly three dozen shops, a police station, high school and paramilitary camp. Two diesel-powered privately run generators supply electricity for 5 hours daily, from 5 p.m. to 10 p.m., to the shops at nominal charges. During the course of the survey, I met the concerned forest officials responsible for CHT North and South Forest Divisions to get permission and assistance in the field. A Dhaka-based wildlife biologist, at least one Forest Department person, one tribal Chakma and one boatman accompanied us in all our surveys of the forest. They helped us to find our way through various watercourses and jungles as well as to communicate with the tribal people in certain areas.

We walked through forests and/or travelled by a slow-moving country boat fitted with an improvised diesel water pump. It followed watercourses surrounding the forests. We also searched inundated banks of the Kassalong river, which is the lifeline for all the forests surrounding it, and probable roosting-nesting sites of the WWD. In addition to this direct observation, several tribal Chakmas, living in all parts of the forest, plains-dwelling Bengali-speaking settlers and some 50 people visiting market places were also interviewed. We showed them the photograph of a WWD and enquired whether they had seen that particular duck, locally called 'Bhadi Hansh' by the tribal Chakmas. We told them its colour and size and explained to them where it usually lived.

Earlier reports of the WWD were mostly from a radius of 5 km from Amtali (23° 03.903' N; 92° 14.686' E). We surveyed the neighbourhood of Amtali during the afternoon and the whole of the next day, both on foot and by boat. We also talked to the villagers, fishermen and boatmen, mostly at night, in the market places where most men of the area gathered to gossip and shop.

On the 4th day, we travelled through Kassalong river and its flooded banks, a marshland where there was a report of the sighting of a pair of WWD by a passing European student, and stopped at several prospective WWD habitats at 23° 05.012' N, 92° 13.774' E; 23° 05.720' N, 92° 13.231' E; and 23° 06.906' N, 92° 13.034' E. We also prospected at the Nalbonia Beel (Beel = low-lying marshland in Bengali) where there was the possibility of its occurrence. We also stopped and watched birds at Shishak Valley. We halted at Marishsha-Baghaichari — the last stop for a motor launch that plies between this and Rangamati town. It is also the headquarters for the Baghaichari Police Station. From there we went to a roughly 5 sq. km marshland named Ugalchari Beel or Lailla Ghona Beel (92° 12.453' E; 23° 08.467' N) and its neighbourhood, and also Bot Tali. Ugalchari village is entirely hilly and dominated by tribal Chakmas, while Bot Tali which is on the bank of Kassalong river is full of settlers. This Beel dries up in winter and is being used for rice cultivation by irrigation. At night we looked for frogs and talked to local folks.

Next morning we left Marishsha for Baghai Haat (23° 16.690' N; 92° 09.091' E). We travelled the first 20 km of the hill road by bus. Then we walked for 8 km to reach Baghai Haat where we stayed for two and a half days. By late afternoon we travelled another 6 km to Ganga Ram (23° 18.073' N; 92° 10.031' E), on the bank of Kassalong river, and the last stop on our journey — beyond this there was no road, and it was not safe for free movement as there was no law enforcing authority there.

From Baghai Haat we made short field trips in different directions and met tribal people who generally congregated in hundreds every Sunday at Baghai Haat to sell their products and to procure provisions.

RESULTS AND DISCUSSION

We did not come across any WWD not only in the Pablakhali Wildlife Sanctuary and its neighbourhood, but also in the entire valley of the Kassalong river up to Marishsha. These included three Beels or marshy areas — Nalbonia Beel, Shishak Valley and Ugalchari Beel. Of these, only the first one is known to hold some water all year round while the others dry up during winter and are used for cultivation of paddy and other winter crops.

Among the persons interviewed, only one Chakma villager from Dhoopchari Bazar, close to

Khan, M.A.R.: Mixed Evergreen Forest in Bangladesh PLATE 1

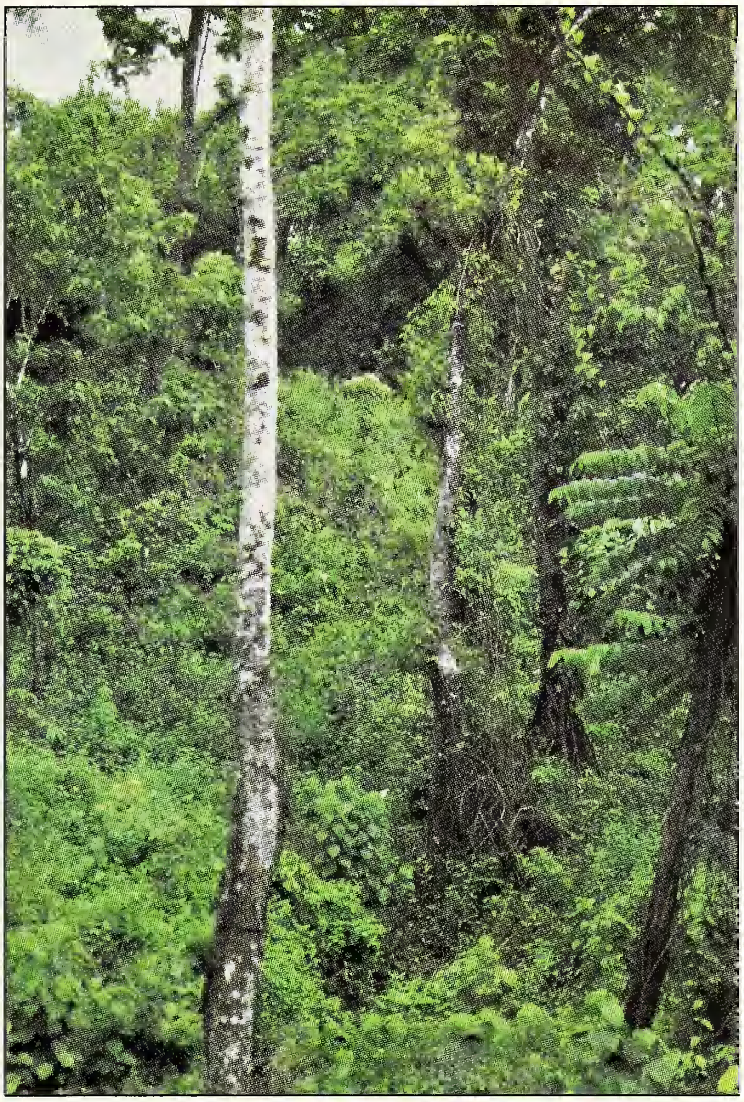

Fig. 1: There are no virgin Mixed Evergreen Forests in Bangladesh — this is one of the best patches with regenerated vegetation

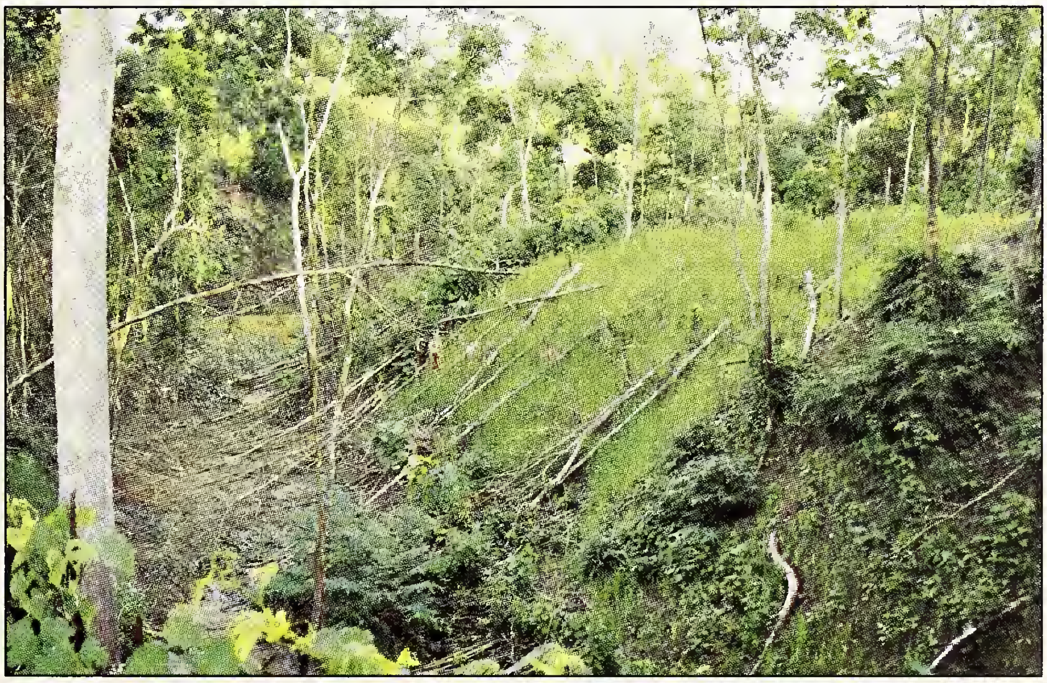

Fig. 2: Tribal *jhum* cultivators have mercilessly cut the trees in the forest, planted paddy, and not even bothered to remove the logs

Khan, M.A.R.: Mixed Evergreen Forest in Bangladesh

PLATE 2

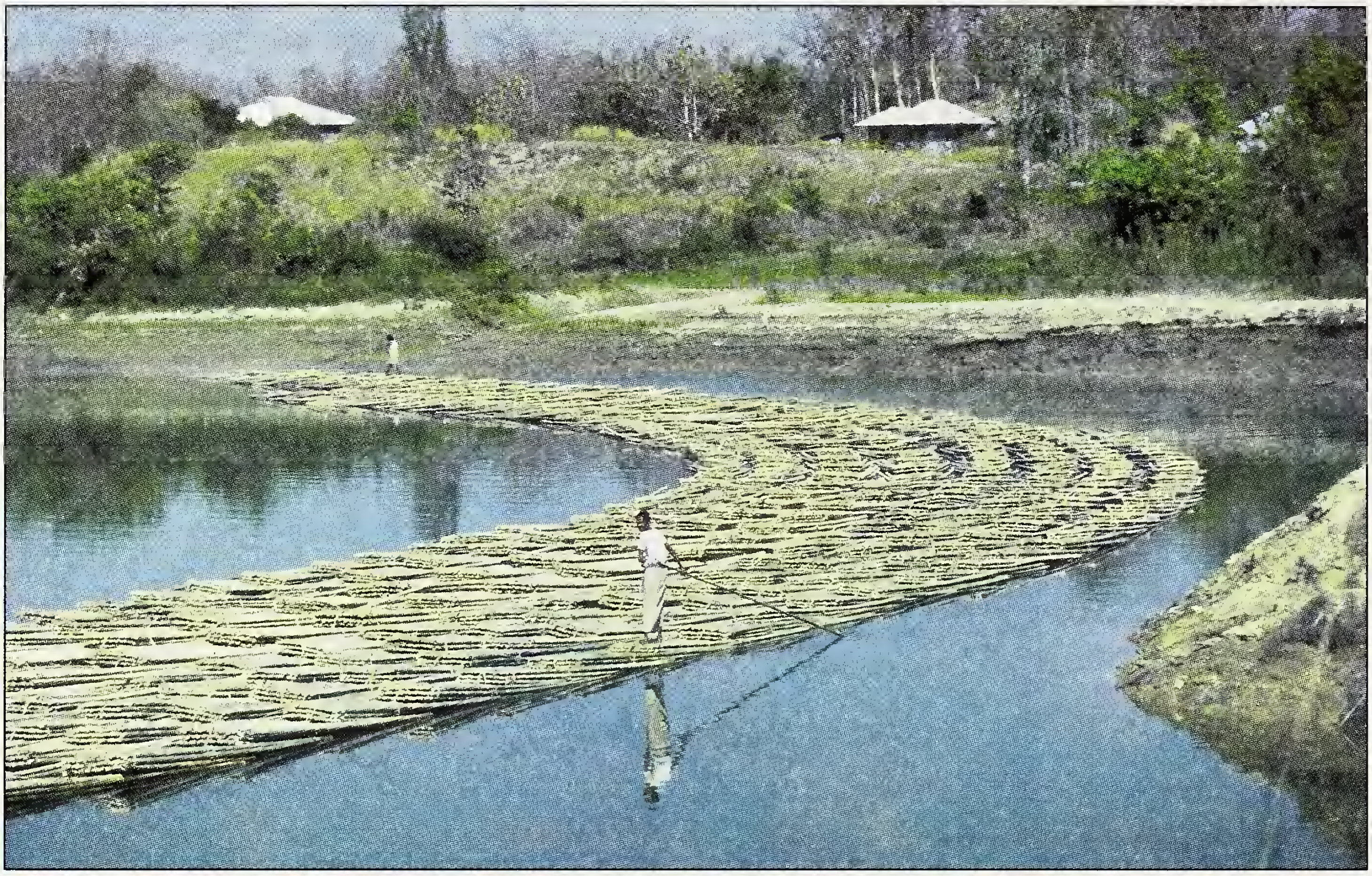

Fig. 3: Clearing reserved forest for housing plains-dwelling settlers and for *jhum* cultivation by the tribal settlers

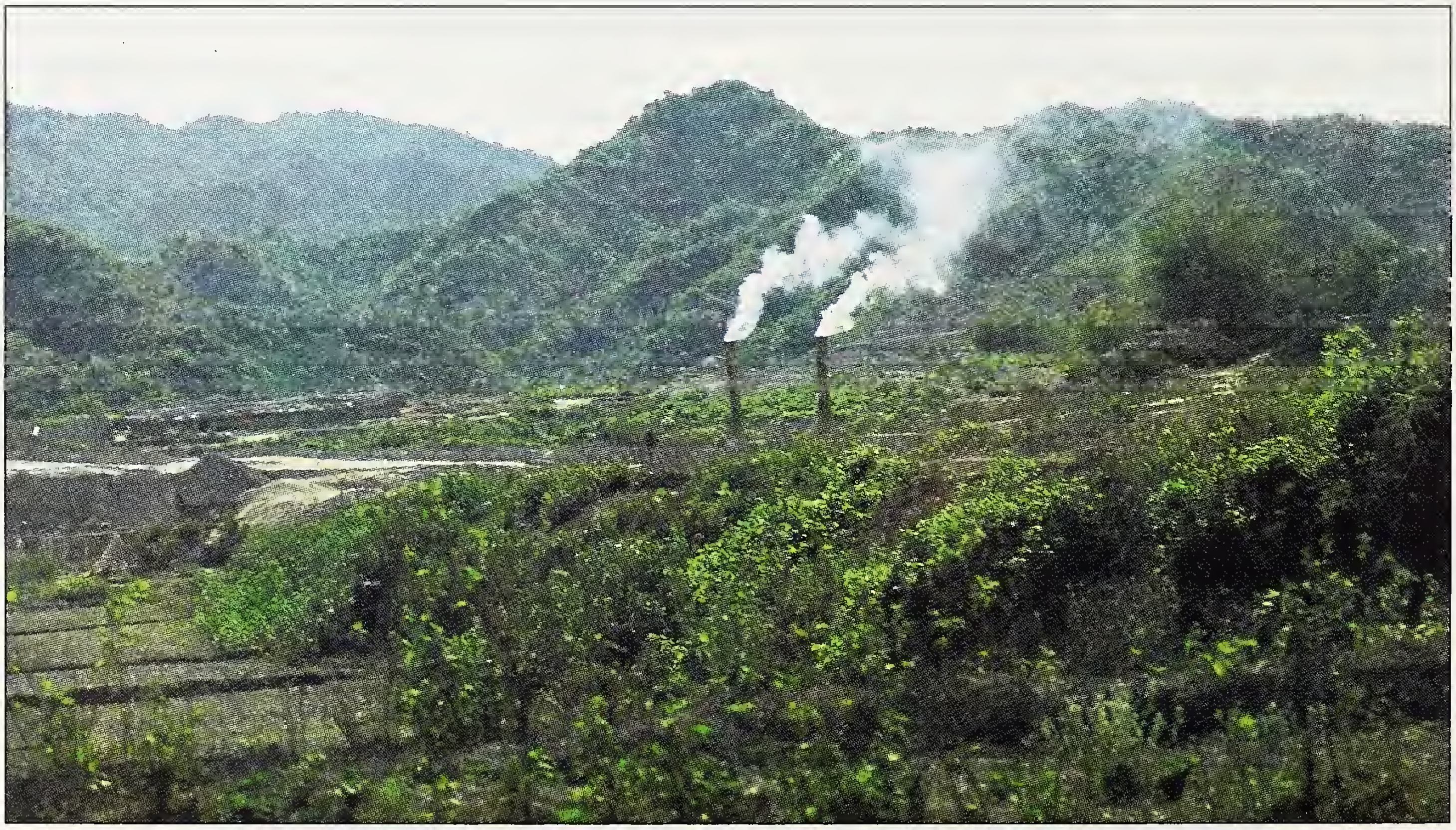

Fig. 4: An officially banned brickfield stands out as a reminder of the ruthless large-scale destruction of the surrounding Mixed Evergreen Forest

the Sanctuary, said that he had seen a pair of WWD in Nalbonia Beel during the previous winter. However, we visited the same area and did not come across any WWD, though we saw a large flock of lesser whistling-duck *Dendrocygna javanica* and a pair of cotton teal *Nettapus coromandelianus* in the same area. We also noted bronze-winged jacana *Metopidius indicus* and chestnut bittern *Ixobrychus cinnamomeus*. There were many domesticated ducks, mostly mallards and muscovies.

As it was the breeding season for most of the fishes, an official fishing ban was in place. A few people were still fishing in the area for their livelihood, but the fish catch was too scanty to feed the local market. So, if there were WWD in the area, it would have been sighted by both Chakmas and Bengali fishermen. From Nalbonia Beel up to Ganga Ram, there was no report of sighting of the WWD.

There is only one recent record of sighting of a pair of WWD between Marishsha and Pablakhali Wildlife Sanctuary, by Neville J. Ash — a British student proceeding towards the Sanctuary searching for bears — on June 5, 1999 (*c.* 23° 10.000' N; 92° 20.000' E), according to Baz Hughes (of Threatened Waterfowl Specialist Group, Slimbridge, UK, pers. comm.). We did not see the duck there during the present survey.

Our past visits during the late 1970s and early '80s, and the present one, revealed a massive change in the pattern of avifauna distribution in the Sanctuary. First and foremost is the excessive abundance of mynas and starlings (*Acridotheres* spp. and *Sturnus* spp.). We came across too many common mynas (*A. tristis*) and Asian pied starlings (*S. contra*) that were very rare earlier and mostly restricted to human habitations. During the present visit, they were found in almost every part of whatever remains of old forests that have been largely converted into *jhum* cultivation through the process of slash and burn.

Another group, the bee-eaters, has flourished. We saw great numbers of blue-tailed bee-eaters, small bee-eaters and chestnut-headed bee-eaters (*Merops philippinus, M. orientalis*, and *M. leschenaulti*) all along the watercourses. We also saw a blue-bearded bee-eater (*Nyctyornis athertoni*) sallying for dragonflies along an oxbow lake. We noted small blue and white-breasted kingfishers (*Alcedo atthis* and *Halcyon smyrnensis*) as very common, but missed stork-billed and oriental dwarf kingfishers (*H. capensis* and *Ceyx erithacus*) noted earlier.

Nearly a dozen species of woodpeckers used to live in this forest. We saw only three species (fulvous-breasted pied woodpecker *Dendrocopos macei*, lesser golden-backed woodpecker *Dinopium benghalense* and little scaly-bellied green woodpecker *Picus xanthopygaeus*) that are also common outside the forested area. We failed to notice any hornbill. Blue-throated and lineated barbets (*Megalaima asiatica* and *M. lineata*) seemed to be more common than the coppersmith or crimson-breasted barbet (*M. haemacephala*). We missed greater and lesser racket-tailed drongos (*Dicrurus paradiseus* and *D. remifer*) but black drongos (*D. macrocercus*) were very common. We noticed much fewer flycatchers and warblers than we saw two decades ago.

During the whole survey period, we had seen only two black-shouldered kites *Elanus caeruleus* at the Sanctuary, and also jungle owlet *Glaucidium radiatum*, spotted owlet *Athene brama*, Eurasian scops-owl *Otus scops* and brown hawk-owl *Ninox scutulata*, but no diurnal birds of prey. Among herons, only the Indian pond-heron *Ardeola grayii* was very common, while the chestnut bittern *Ixobrychus cinnamomeus* was not so common. We did not see any cormorant (*Phalacrocorax* spp.), little grebe (*Tachybaptus ruficollis*) or moorhens (*Porphyrio* sp. and *Gallinula* sp.).

The largest warbler in the area is the striated marsh-warbler *Megalurus palustris* and it was as common as before, but rewarding was the sighting of quite a few pied bushchats with juveniles

(*Saxicola caprata*). Red-vented bulbuls *Pycnonotus cafer* outnumbered all the forest bulbuls. Olive bulbul *Iole virescens* and red-whiskered bulbuls *Pycnonotus jocosus* were also common. Among flycatchers we saw a few black-naped monarch-flycatchers *Hypothymis azurea*, a niltava (*Niltava* sp.) and another blue flycatcher (*Muscicapa* sp.). Among sunbirds and flowerpeckers, the purple-rumped sunbird *Nectarinia zeylonica* and scarlet-backed flowerpecker *Dicaeum cruentatum* dominated the rest. The common iora *Aegithina tiphia* and oriental white-eye *Zosterops palpebrosus* were also very common.

Among mammals we observed the Irrawady squirrel *Callosciurus pygerythrus* to be the most common diurnal species. In addition, we noted Malayan giant squirrel *Ratufa bicolor*, rhesus macaque *Macaca mulatta*, a troop of capped langur *Trachypithecus pileatus*, a small herd of 5-6 elephants *Elephas maximus*, flying fox *Pteropus giganteus* and false vampire bat *Megaderma lyra* as common, and pygmy/Indian pipistrelle *Pipistrellus mimus* as a very common species.

The reptiles we noted included checkered keelback *Xenochrophis piscator*, common skink *Mabuya carinata*, Bengal/common Indian monitor *Varanus bengalensis* and common garden lizard *Calotes versicolor*.

Among frogs, we noted treefrogs *Polypedates leucomystax* and *P. maculatus*, common toad *Bufo melanostictus*, skipping frog *Euphlyctis cyanophlyctis*, Indian bull frog *Hoplobatrachus tigerinus*, cricket frog *Limnonectes limnocharis*, Boulenger's frog *Rana alticola*, ornate microhylid *Microhyla ornata* and red microhylid *Microhyla rubra*.

There appeared an appreciable change in the sightings of mammals and reptiles. We saw only one group of langurs and a pair of Malayan giant squirrels, and one each of *Calotes* and *Mabuya*. However, these species used to be common or very common in the 1970s and early 1980s.

CONSERVATION ISSUES

We may safely conclude that the WWD has disappeared from the Pablakhali Wildlife Sanctuary. Even if a stray pair or two are alive in some pockets, it is only a matter of time before these will either be trapped, netted, or hunted down with guns that have become freely available in the area.

If we try to find the reasons behind the disappearance of the WWD, we will arrive at the reasons for the large-scale destruction of other biodiversity from the region. The present study points out to several important but chronic causes. These are:

***Jhum* cultivation**: This is the slash and burn process, of clearing a patch of natural forest and planting paddy and other cash crops, carried out by the tribals. Such a cleared field area is used alternately every 3rd or 4th year. The moment a forest is removed from an area, the topsoil is washed downhill by the monsoon rain. By repeated *jhum* cultivation, the soil loses its fertility and such fields are soon taken over by exotic plants or invasive local species of no commercial value. Such problematic species include the twiner *Mikania scandens*, shrubs such as *Eupatorium odoratum*, *Lantana camara* and thatching grass *Imperata arundinacea*.

Back in 1875, the then Conservator of Forests in Bengal, Sir William Schlich, noted that *jhum* cultivation was the enemy number one for the existence of natural forests in CHT District (based on Forest Department reports). The British, up to 1947, the East Pakistan authorities up to 1971, and the present Bangladesh authorities have not been successful in dissuading the tribal people from practising this slash and burn process of cultivation in all the three Hill Districts (Plate 1, Fig. 2).

Clear-felling and monoculture: The British, followed by the East Pakistan, and the present Bangladesh Forest Authorities, had and have one common goal in mind — to send more and more revenue to the government exchequer by selling natural trees and other forest produce. This trend was consistent in the past and is continuing unabated to date. To do this they utilised the simple process of 'clear-felling' operations, on a predetermined basis prescribed in the 'Working Plan' prepared by a forest staff member for a Forest Division. In this process, all timber and commercially important species of trees are removed first, followed by planting of saplings of a single commercially viable species of timber such as teak (*Tectona grandis*), jarul (*Lagerstroemia reginae*), dipterocarp (*Dipterocarpus* spp.), jamun (*Syzygium cumini*), etc., as monocultures. Trees grown under monoculture are also removed on the basis of short or long rotations ranging from 20 to 60 years. The planting activities were assisted by tribal Chakmas and forest-villagers. In exchange for their labour, they would be allowed to burn all other plants from the monoculture area and start cultivating *jhum* rice and other crops. The *jhumias* stayed there for the first two years to take care of government forest while cultivating their own crop in the area. They also helped remove the weeds from the plantation. These processes resulted in the large-scale removal of natural forest, encouraged *jhum* cultivation in reserved forest area and allowed encroachment of forested land by the forest villagers (Plate 2, Fig. 3). At the end of it all, wildlife was wiped out from the area.

Construction of Kaptai Dam: Under a fund from USAID during 1959-63, the then East Pakistan Government constructed the Kaptai Hydroelectric Project with a view to generating 230 MW power for the country (now Bangladesh, after December 1971). Unfortunately in 1992, the power production in the project area went down to an all time low of 30 MW, due to shortage of water and filling up of both the lower and upper reaches of the lake by accumulated silt that resulted from deforestation in the hilly areas. When fully commissioned in 1962, the Project inundated an estimated area of 655 sq. km that included 40% of the best cultivable land in the former CHT District (Gain 1995). Due to this project the Kaptai Lake — an artificial one — has been created. This dam has displaced at least 20,000 plough and *jhum* cultivating Chakmas from the Kassalong Valley. It destroyed an entire ecosystem from the valley floor up to about 10 m. This was a one time colossal loss of biodiversity in CHT.

The Chakmas and some settlers from the 1950s and early '60s allotment of valley lands, who were affected by the creation of the Kaptai Dam in 1965, were ultimately resettled in a section of the Kassalong Valley Reserve Forest in the late 1960s. This also destroyed the wildlife and its habitat.

Negative management of wildlife: Bangladesh Government ended all its responsibilities of managing the nation's wildlife wealth, by promulgating the Bangladesh Wildlife Preservation Order/Act 1973 and appointing a lone Senior Research Officer under the Forest Directorate. This person is now retiring in the same post, in a year or two. The Government has also declared a few areas as National Parks, Wildlife Sanctuaries, Game Reserves, Bird Sanctuaries, etc., under the above Act, as well as Biosphere Reserves and a World Heritage Site, under pressure from western donor countries. But all of these are only on paper and not in practice. The Government has utterly failed in managing the country's forests and wildlife (Plate 2, Fig. 4).

Settlements: Towards the end of the 1970s, the Bangladesh Government decided to settle plains-dwelling and Bengali-speaking people *en masse* in the Bandarban, Khagrachari and Rangamati Hill Districts, which traditionally used to be the home of the tribal people only. I understand, over a period of a decade or so, the Government was able to settle about 25,000 Bengali families in the hilly areas, including government-reserved forests. Each family was allotted a plot of 5 acres of hilly land, 4 acres of mixed land and 2.5 acres of paddy land (Gain 1995). These settlers first chopped and sold all valuable timber trees from their allocated areas and then moved on to encroach upon more and more government forests as they had very little place to practise agriculture. It was an easy way of getting quick money by selling trees and other forest produce. Ultimately, they started encroaching upon both government revenue (*khas*) and forested lands. The population of the settlers must have doubled during the past two decades or so. Their demand for land and forest is never ending. Also, these people have negative social interaction with the tribal people due to cultural conflicts (Gain 1995).

Tribal insurgency: To counter the settlement of plains-dwelling Bengali people in the hilly areas of the erstwhile CHT District, a section of the tribal Chakmas formed a resistance group called 'Shanti Bahini' meaning Peace Force. This tribal insurgency continued roughly from 1980 to 1998. During the insurgency period, the Government brought in their counter-insurgency machinery such as the Military, Para Military BDR (Bangladesh Rifles), Police, Ansars, VDP (Village Defence Party), and a number of civil administrations. It is conjectured that during this long period, all sides and parties involved in the conflict destroyed forests and wildlife in an unabated fashion. The trend continued even after a peace deal was signed between the Shanti Bahini and Bangladesh Government in early 1998 when the tribals surrendered their arms. When I visited the area between February 18 and 22, 1998, and during the course of the present study, I documented the rampant destruction of forests and wildlife in the Sanctuary.

Presently it seems that nobody is in control of the CHT forests. It has become a free for all situation, with Chakmas and other tribals randomly cutting reserved forests and even government forests of monoculture just created in the 1990s, considering it to be their right. Taking advantage of the prevailing situation, the Bengali settlers are removing as many forest trees as possible to meet their daily needs as well as in greed. All law-enforcing authorities are apparently sitting idle. Possibly, they do not like to get involved in any conflict. Overall, the social situation seems to be tense between the tribal Chakmas and Bengali settlers, as there is no free exchange between the two communities. Meanwhile, forest destruction and killing/capturing of wildlife are continuing unhindered.

RECOMMENDATIONS

a. First of all, parties occupying the area must restore peace and tranquillity in the area without which there can be no development for either the Bengali-speaking settlers or the ethnic tribal people.

b. Specifically for the WWD: If any duck of this species is captured it must be saved. The way to do this is to buy back the duck from the tribal Chakmas or Bengali settlers by bartering it for domesticated ducks. People who live in the area should be given material incentives to protect the WWD in their area. Domesticated ducks and poultry have good cash value and a certain number of these can be given to those families who live in the WWD area. This will allow the unhindered existence of the species.

   However, there must be a Government or NGO unit to facilitate these barter deals and oversee the project, from inception to implementation. This unit should ensure that sufficient funds are available to rehabilitate any ducklings produced. A certain number of ducklings can even be taken away to a few captive-breeding centres within the tribal area or outside it, with a view to bringing back the grown birds for reintroduction into the former range within the Sanctuary or its neighbourhood.

c. *Jhum* cultivation should be restricted only to areas where *jhum* fields already exist. Further denudation of forest must be stopped, as tribals themselves are not likely to get any land in the future to practise *jhum* cultivation if the current trend continues.

d. No new monoculture should be allowed. Instead, mixed species of indigenous trees should be planted and nurtured, with emphasis on fruit bearing and softwood trees that allow animals to get food and nesting opportunities. At least one third of the existing reserved forest should be declared as a Nature Reserve where forestry, agriculture or settlement activities of tribals or plains-dwellers should be stopped for at least half a century. This will allow the forest to regenerate on its own, and the biodiversity can get a foothold and revive to a certain extent.

e. A separate Wildlife or Biodiversity Bureau should be created under the Environment and Forest Ministry. All lands declared previously as National Parks, Wildlife Sanctuaries, Game Reserves, Nature Reserves, World Heritage Site, Biosphere Reserves, etc., and to be so declared in the future, must be handed over to this new Bureau for their total management. These areas will have no administrative tie with the Environment or the Forest Department. This organisation is also to be banned from altering existing habitats for commercial purposes. Instead it must aim at scientific and sustainable management of biodiversity. It must try to practise sustainable utilisation of the natural resources.

f. All zoos, wildlife research institutes and captive breeding centres existing in the country must be incorporated under this Wildlife Bureau.

g. Top-level managers of the Bureau must be recruited at a national level, and have a wildlife background. Professionals from other disciplines such as Botany, Geology, Soil Science, etc., should also be involved in the activities of the Bureau. The rest of the manpower can be recruited locally. Only trained local people should be involved in the field level activities in all wildlife/biodiversity areas. No foreigners should be incorporated in the activities of the Bureau. However, foreign advisors can help the Bureau in future planning and project designing.

h. The Bureau would be responsible for the development of wildlife/biodiversity curricula for all levels of education in the country.

i. It should encourage ecotourism in all managed areas.

j. It must enrich spoilt habitats by planting suitable indigenous tree species, especially those with soft, fleshy fruits and colourful, nectar producing flowers, various fig species and softwood trees suitable for hole-nesting animals.

k. The Bureau must be active in raising public awareness campaigns. It must popularise Biodiversity Conservation in the country and take part in all activities of international bodies like the CITES Authority, IUCN - the Conservation Union, WWF (Worldwide Fund for Nature), and WAZA (World Association of Zoos and Aquariums).

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THE INCUBATION MOUND AND HATCHING SUCCESS OF THE NICOBAR MEGAPODE *MEGAPODIUS NICOBARIENSIS* BLYTH

(*With four text-figures and one plate*)

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Key words: Incubation mounds, Nicobar megapode, hatching success, megapodes, *Megapodius nicobariensis*

Incubation mounds of the Nicobar megapode *Megapodius nicobariensis* were constructed with sand or sand with plant materials, such as leaves, twigs and bits of decomposing wood. Usually, the site selected for a new incubation mound was a fallen log, tree stump, or the decomposing roots of a tree. Mound construction begins with the birds either digging a pit at the site or by covering the decomposing log or tree stump with soil and litter. The mean egg-laying interval was 14.91 ±1.43 days, the average number of eggs laid in a mound was 4.5 ±0.6 eggs, but it significantly varied between the years and the average clutch size of the Nicobar megapode was 2.75 ±0.35 eggs. Moderate rainfall in the dry season enhances egg production. Microbial activity appears to be the primary source of heat within mounds. The size of the mound was positively correlated to the temperature within the mound. The average incubation temperature was 32.44 ±0.21 °C and the average incubation period was 74.73 ±0.52 days. There was, however, no significant relationship between the mound size and hatching success of the Nicobar megapode.

INTRODUCTION

Megapodes are unique among birds because they incubate their eggs in mounds of rotting leaves or in burrows in geothermally heated ground (Frith 1956, Dekker and Wattel 1987, Jones 1988, Dekker 1990). Perhaps the best-studied aspects of the Megapodiidae are the incubation conditions within mounds and communal nesting grounds (Frith 1956, 1959, Crome and Brown 1979, Seymour *et al.* 1986, Booth 1987, Seymour *et al.* 1987, Dekker 1988, Jones 1988).

Within the Megapodiidae, there exist two groups, burrow nesters and mound builders with variations in the incubation and breeding strategies. Burrow nesting species like *Macrocephalon* and *Eulipoa* lay eggs at communal nesting grounds where sun or volcanic activity provides heat for incubation (Dekker 1988, 1990, Heij *et al.* 1997). *Talegalla, Aephypodius, Alectura* and *Leipoa* build incubation mounds of forest litter where organic decomposition provides necessary heat (Dekker 1990). Of the 13 species that comprise the genus *Megapodius*, 10 are mound builders, two are burrow nesters, and one nests in both burrow and mound (Jones *et al.* 1995). The Nicobar megapode *Megapodius nicobariensis*, a monomorphic mound building megapode (Plate 1, Figs 1,2), endemic to the Nicobar Islands in the Bay of Bengal, builds incubation mounds of sand, loam, coral bits and rotting vegetation, within which eggs are laid. Incubation mounds of the Nicobar megapode vary in type, size and location (Dekker 1992, Sankaran 1995, Sankaran and Sivakumar 1999, Sivakumar and Sankaran, in press). Some mounds have a greater admixture of vegetative material, while others have a greater amount of sunlight falling on them, which suggests that the source of heat varies between mounds. In this paper, we address the questions consequently raised: which sources of heat provide the most stable incubation conditions? Do sources of heat that create suitable

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incubation conditions within mounds vary with mound type, location and dimensions? And do heat sources and mound dimensions have a bearing on the number of pairs that use a mound, the number of eggs laid, and hatching success?

STUDY AREA

The Andaman and Nicobar Islands (6° 45' to 13° 41' N, 92° 12' to 93° 57' E), in the Bay of Bengal, arch from Arakan Yoma, Myanmar in the north to Sumatra, Indonesia in the south (Saldanha 1989; Fig. 1). These islands cover an area of 8,249 sq. km with a coastline of 1,962 km. The Andaman group with more than 325 islands (21 inhabited) covers an area of 6,408 sq. km. The Nicobar group with over 24 islands (13 inhabited) covers an area of 1,841 sq. km (Singh 1981, Saldanha 1989).

We studied the ecology of the Nicobar megapode between December 1995 and July 1996, December 1996 and June 1997, September and October 1997, and February and May 1998. The study period includes three dry seasons (peak period of egg laying) and part of one wet season. Our study area was on the coast at the southern tip of Great Nicobar Island. The intensive study area was a narrow strip of forest, of width varying between 40 and 300 m and length about 4 km, which was bisected by a disused metalled road, ending at the light house at Indira Point. The beach forms the boundary to the study area in the east, and wetlands or forests that are inundated during the monsoons form the boundary to the west. The soil within this strip of coastal forest was sandy and loamy, and the dominant trees were *Barringtonia asiatica*,

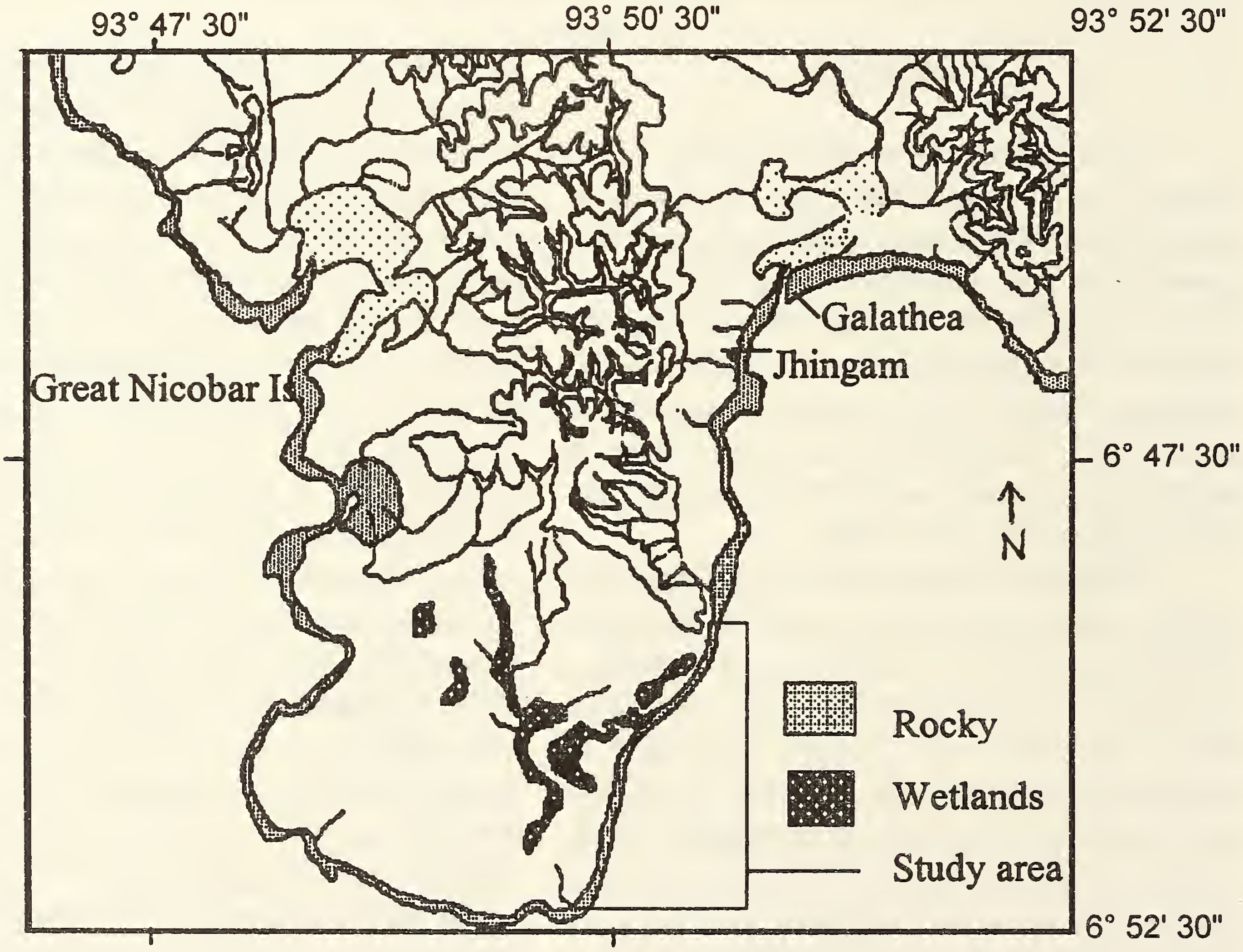


Fig. 1: Southern part of the Great Nicobar Island showing the study site

Sivakumar, K. and R. Sankaran: Nicobar megapode *Megapodius nicobariensis* PLATE 1

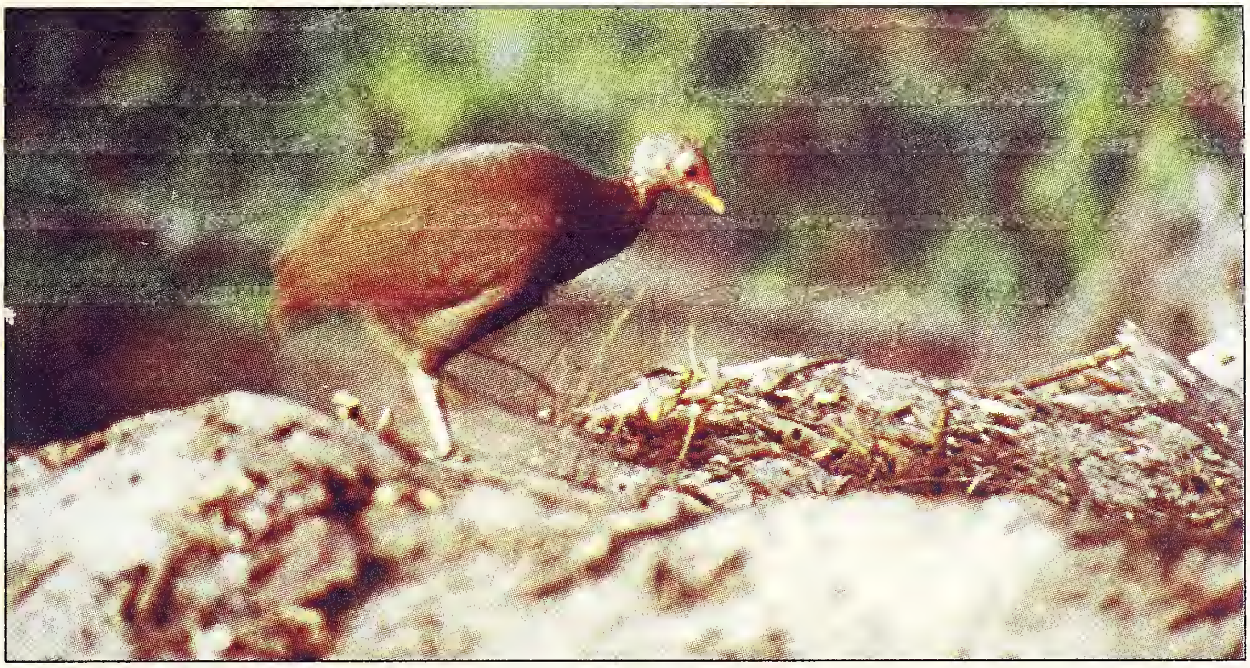
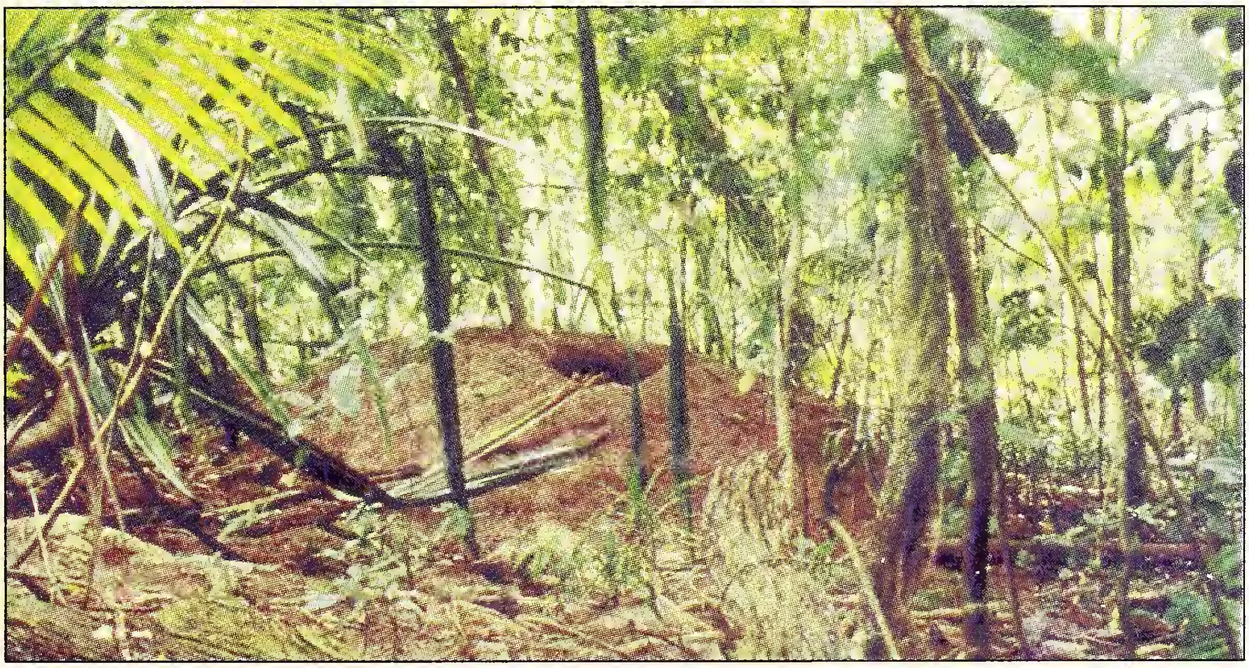


Fig. 1: Nicobar megapode on the mound it has built



PICS: RAVI SANKARAN

Fig. 2: Another incubation mound of the Nicobar megapode

B. racemosa, *Terminalia bialata*, *Terminalia catappa*, *Syzygium samarangense*, *Thespesia populnea* and *Macaranga* spp. The study area had dense stands of *Pandanus tectorius* and *P. odoratissimus* in patches, and the road was fringed by stands of *Lea angulata*, *L. grandifolia*, and *Dracaena* spp. There were a few patches of open ground with little vegetation. The forest forming the boundary of the study area to the west had wet clayey soil and was covered with *Areca* spp. as well as trees like *Ixora barbata*, *Pongamia pinnata*, *Alstonia kurzii*, *Adentania paranina*, *Aisandra butyracea*, *Horsfieldia irya*, *Myristica andamanica*, and *Celtis timorensis*.

METHODS

At the start of the study or whenever a new mound was constructed, detailed drawings of the mounds were made to scale using measuring tapes and a compass, and salient characteristics such as living trees and dead logs or tree stumps were plotted on these. The basal circumference, height and diameter of the mounds were measured once a month. Mounds were uneven in shape with a cone-like appearance. The mound size, expressed as volume, was derived from the equation for the volume of a cone: $1/3\pi r^2h$ where 'r' is the radius and 'h' the height, giving the approximate volume of the mound.

All the incubation mounds in the study area were visited at least twice a day, in the morning and in the evening and occasionally during midday, to identify whether megapodes had worked on the mounds, and what type of activity they had engaged in. At four mounds, the megapodes were intensively observed, following the focal animal sampling method (Altmann 1974), from observation hides. Observations from the hide usually started before the arrival of birds at the mound (at 0500 to 0530 hrs) and ended after the birds left the mound. Observation recommenced at about 1400 hrs and was carried on till dusk. The activities of the birds were classified into: visit, pit digging, egg laying, raking, covering, pits-filled, and random activity.

In 1996, four temperature probes were implanted at depths between 20 and 75 cm, in seven mounds that had been selected for intensive studies. However, after about two months these probes malfunctioned, probably due to high humidity and rainfall. In 1997 and 1998, a temperature probe placed at the tip of a one metre long steel tube was inserted to depths of 30, 60 and 90 cm to measure the temperature. Using this method the temperatures were measured once a month for all the mounds in the study area, every 15 days for the target mounds, both in the morning and evening. Occasionally the temperature of the mound was also measured during midday.

Microbial activity was measured using a soil respirometer (PP Systems EGM-1 Environmental Gas Monitor with a SRC-1 Soil Respiration System), assuming that in those mounds where microbial activity was high, greater amounts of CO_2 would be emitted. The soil respirometer measures the CO_2 change in a fixed volume over a known time and fits a quadratic equation to the data to arrive at a value 'SR' which is the soil respiration rate in $gCO_2/m^3/hr$. Soil respiration was measured once every 10 or 15 days for the seven mounds that were under intensive study. Like temperature, data on the soil respiration of mounds was collected both in the morning and evening.

The intensity of light falling on the mound at different times of the day was measured using a luxmeter. The amount of Photosynthetic Active Radiation (PAR) falling upon the mound and PAR absorbed by the mound were measured using Sunfleck Ceptometer (Decagon, Pullman, WA). This was also measured outside the mound. The gap in the canopy cover above the mound was measured using a concave mirror that was uniformly graduated.

Soil samples were collected from the surface of the mound and then sun dried for an hour.

Percentage of humidity was measured by using the following formula:

Humidity (%) = [(Wet soil weight - Sun dried soil weight) / Wet soil weight] x 100

During the breeding seasons of 1996, 1997 and 1998, thirty-seven mounds were monitored. When an egg was laid, it was dug out and weighed to the nearest gram using a spring balance. Eggs were also measured with Vernier callipers and marked with a number and date using an HB graphite pencil. After weighing and marking, the eggs were reburied in the same egg chamber and the mound was rebuilt. For identification, a stick was placed adjacent to the egg chamber. During 1997 and 1998, thirty-four eggs were directly marked and monitored. The marked eggs were monitored by rechecking them once every 15 days. At the beginning of 1998, all the mounds were thoroughly checked with the help of mound maps of 1997, where the locations of eggs were clearly plotted. Successful hatching of eggs was evident from eggshell fragments and pieces of shell membrane where the eggs had been. Emergence of the chick from the egg during hatching and its subsequent activity was observed by placing a glass plate adjacent to the egg on the day of egg laying. In 1998, a total of seven eggs were monitored for the same. Eggs which remained in the mounds for the entire breeding season, or those which did not hatch for 100 days were opened and examined.

RESULTS

Description of incubation mound of the Nicobar megapode

Of the 38 incubation mounds present in the study area between 1996 and 1998 (Table 1), three were type 'A' incubation mounds built on an open spot away from trees, three were type 'B' incubation mounds built against a large living tree, and 25 were type 'C' incubation mounds built on or around a dead log or stump. Of the remainder, four incubation mounds were type 'BC' (built against the buttress of a partially living tree, or with a dead log in it), of which two later became type 'C' in 1998 because the trees died out completely. One incubation mound was type 'AB' as it was built in the open with two living *Pandanus* palms in it (Table 1). Two incubation mounds were unusual, as they were built against the edge of the disused metalled road that bisected the study area (type 'R'). Among the16 incubation mounds that were newly constructed during the study period, 13 were type 'C' incubation mounds, one was a type 'B' incubation mound, and two were built against the road (Table 1).

The construction and maintenance of an incubation mound involves several activities. Usually, the site selected for a new incubation mound is a fallen log, tree stump, or the decomposing roots of a tree. The megapodes began construction of the new incubation mound either by digging a pit if the site was over decomposed roots or by covering the decomposing log with soil and litter raked in from the surrounding areas. The process of raking soil and litter on to the site, or the piling up of soil and other material over the pits, soon resulted in the formation of a new incubation mound.

Temperature and soil respiration in and out of the incubation mound

Mean core temperature at the depth of 50-60 cm in an incubation mound was 31.94 °C (SE 0.075, n=634). It was higher than the forest ground where it was 28.72 °C (SE 1.66, n=105) at the same depth. The mean soil respiration rate (SR in $gCO_2/m^3/hr$) on the active incubation mound was 5.55 (SE 0.13, n=920), which was always higher than that on the abandoned incubation mound (SR= 2.88, SE 0.92, n=140) as well as the normal ground (SR = 3.7, SE 0.86, n=130).

Incubation period and optimal incubation temperature

Incubation temperature (mound core temperature) of the 34 egg chambers in 16 different

Table 1: The history of incubation mounds of the Nicobar megapode in the study area

S. No.	Mound Code No.	Birds/ year	First located on	End date	Status	Type	Distance from the shore (m)	Average size[1] (cu. m)
1	10	10	5-Jan-1996	May-1998	PS	A	25	40.24
2	4	7	3-Jan-1996	May-1998	PS	BC	25	15.31
3	13	7	5-Jan-1996	May-1998	PS	C	240	12.88
4	16	-	17-May-1997	May-1998	NF	A	5	12.12
5	12A	3	3-Feb-1996	May-1998	NF	C	185	9.14
6	14	11	28-Jan-1996	May-1998	PS	C	105	8.98
7	12	4	5-Jan-1996	May-1998	PS	C	205	8.17
8	8	18	3-Jan-1996	May-1998	PS	BC	27	8.02
9	10B	3	7-May-1997	May-1998	NC	C	132	6.98
10	5	2	3-Jan-1996	Jan-1996	PS	C	85	6.88
11	9	16	5-Jan-1996	May-1998	PS	BC	83	6.67
12	12B	2	28-Jan-1997	Apr-1998	NF	C	190	6.26
13	3	7	3-Jan-1996	May-1998	PS	BC	20	4.03
14	2	2	3-Jan-1996	Feb-1997	PS	A	15	3.98
15	15	2	5-Feb-1996	Mar-1998	NF	C	160	3.74
16	9A	4	30-Jan-1996	Feb-1998	PS	AB	95	3.11
17	8C	1	11-Apr-1998	May-1998	NC	C	42	2.96
18	6	6	3-Jan-1996	May-1998	PS	C	74	2.74
19	1	5	3-Jan-1996	May-1998	PS	C	52	2.29
20	9C	9	13-Feb-1997	Apr-1998	NC	C	80	2.02
21	7C	1	26-Sep-1997	Mar-1998	NC	B	22	1.75
22	8A	1	19-Mar-1996	Mar-1998	NF	C	110	1.57
23	8D	1	11-Apr-1998	May-1998	NC	C	6	0.99
24	7	5	3-Jan-1996	May-1998	PS	C	105	0.93
25	1B	2	23-Apr-1997	May-1998	NC	C	15	0.76
26	10D	1	27-Mar-1998	May-1998	NC	C	8	0.76
27	11	2	5-Jan-1996	May-1998	PS	C	195	0.76
28	7A	2	3-Jan-1996	May-1998	PS	C	105	0.66
29	13A	1	19-Mar-1997	Feb-1998	NC	R	120	0.64
30	10A	2	7-May-1997	May-1998	NC	C	35	0.50
31	9B	1	10-Feb-1996	Feb-1998	NC	B	10	0.49
32	8B	1	27-Mar-1998	May-1998	NC	C	10	0.39
33	13B	1	19-Mar-1997	Feb-1998	NC	R	120	0.38
34	11A	2	12-Feb-1996	Feb-1998	NC	C	180	0.37
35	1A	3	16-Apr-1997	May-1998	NC	C	15	0.35
36	6A	3	21-Mar-1996	Apr-1998	NF	B	30	0.32
37	7B	1	6-Feb-1998	May-1998	NC	C	20	0.26
38	10C	1	5-Sep-1997	Feb-1998	NC	C	130	-

NC= New construction; PS= Present at start of study, NF= Newly found.

[1] As mounds change in size over time, the mean value for all mound size data collected during the study is given.

mounds was monitored, and the incubation period for 30 eggs determined. The remaining four eggs did not hatch. The shortest incubation periods were 70 days (n=1 egg) and 72 days (n=6 eggs) and the longest incubation period was 81 days (n=1 egg). The mean temperature of the egg chamber for successful hatching was 32.44 ±0.21 °C (n=30). The mean incubation period of the monitored eggs was 74.73 ±0.52 days. Though the data (Fig. 2) indicates that as temperature decreased the incubation period increased, there was no significant negative correlation between the length of incubation period and incubation temperature ($r = -0.31$, $n=30$, $p=0.095$). Moreover, as eggs incubated at different temperatures hatched in almost the same period, it also indicates that minor fluctuation in the temperature of the egg-chamber did not affect the incubation period significantly.

Effects of incubation mound size on incubation temperature

The effect of mound size on the incubation temperature in 37 incubation mounds was studied. The sizes of the 37 incubation mounds varied from 0.15 cu. m to 40.24 cu. m, with a mean size of 4.78 cu. m (SE 1.19). As mound size increased, the temperature of the mound also increased (Fig. 3) at the depth of 30 cm ($r =0.162$, $n=518$, $p<0.001$), 60 cm ($r =0.177$, $n=532$, $p<0.001$) and 90 cm ($r =0.307$, $n=526$, $p<0.001$). Within a mound there was some fluctuation in the incubation temperature, irrespective of sizes (Fig. 3).

Table 2: Average temperature (in °C) of the mounds at various depths

	Ambient	Surface	Upper layer	Middle layer	Deep layer	Deepest layer
Mean	28.17	27.57	29.91	30.65	31.94	32.51
n	735	745	196	618	634	628
SE	0.065	0.055	0.177	0.074	0.075	0.072

Role of sunlight in incubation temperatures

Intensity of the light (lux value) significantly enhanced the ambient temperature ($r=0.24$, $n=168$, $p<0.01$) and surface temperatures of the mound ($r =0.25$, $n=168$, $p<0.01$) but not that of the mound core ($r =0.053$, $n=96$, $p=0.610$). However, there was a positive correlation between the surface and the mound core temperature ($r =0.23$, $n=626$, $p<0.001$). The mean ambient and surface temperatures were always lower than the mound temperatures at different depths (Table 2).

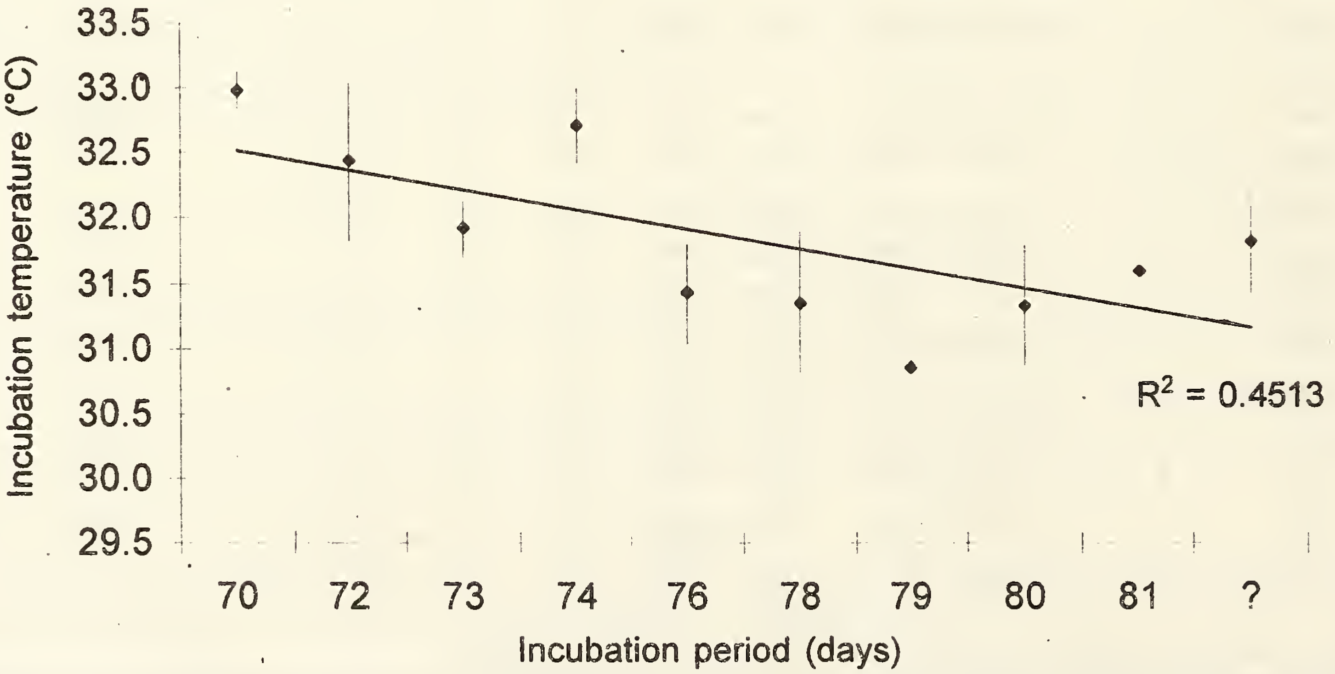


Fig. 2: The relation between the incubation temperature (°C) and incubation period (days) of egg of the Nicobar megapode (Standard error of the mean shown as error bar, '?' are unhatched eggs)

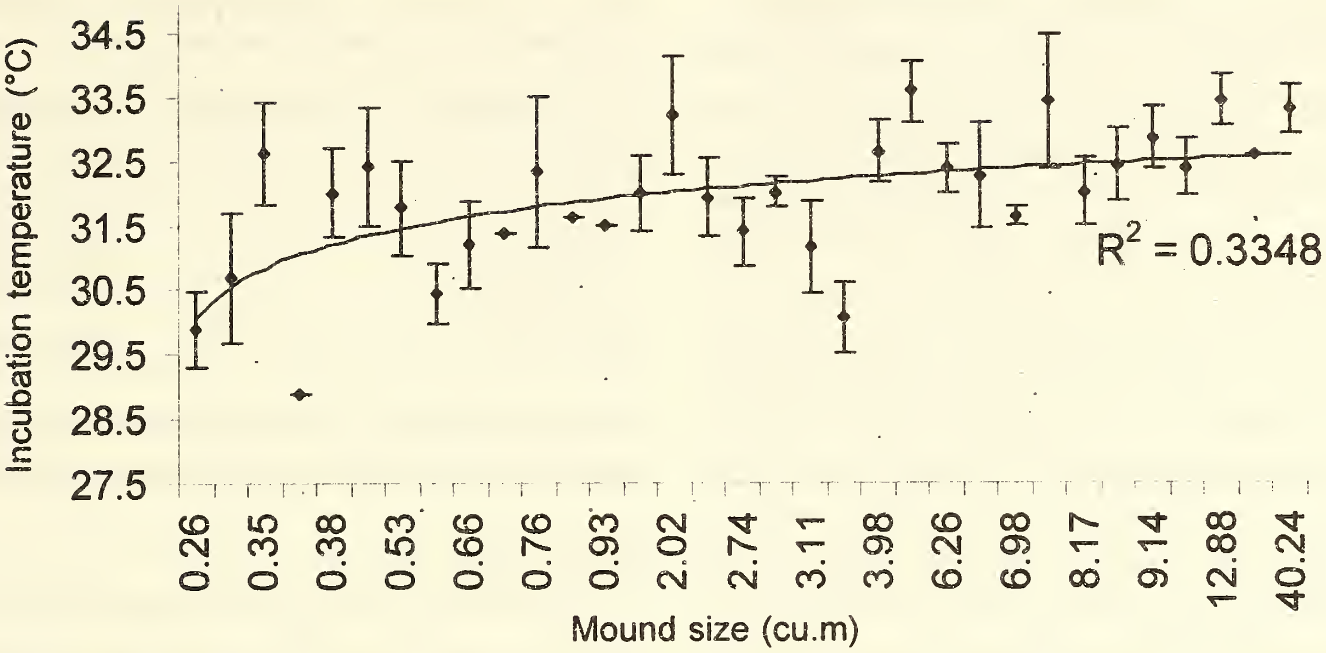


Fig. 3: Relation between mound size and incubation temperature of the Nicobar megapode (Standard error of the mean temperature shown as error bar)

Role of microbial activity in mound incubation temperatures

There was a significant positive correlation between soil respiration rate and the incubation temperature of the mound (r=0.15, n=204, p=0.02; Fig. 4).

Effect of moisture content of the mound on incubation temperature

Moisture content of the mound soil highly influenced the intensity of the mound temperature. An increase in the moisture content of the soil resulted in an increase in mound temperature at the different depths studied, as follows: 30 cm (r=0.272, n=166, p<0.001), 60 cm (r=0.407, n=166, p<0.001) and 90 cm depth (r=0.534, n=166, p<0.001). We did not estimate the soil respiration rate when the moisture content of the soil was estimated, as a result of which the influence of moisture on the microbial activity of the soil could not be established.

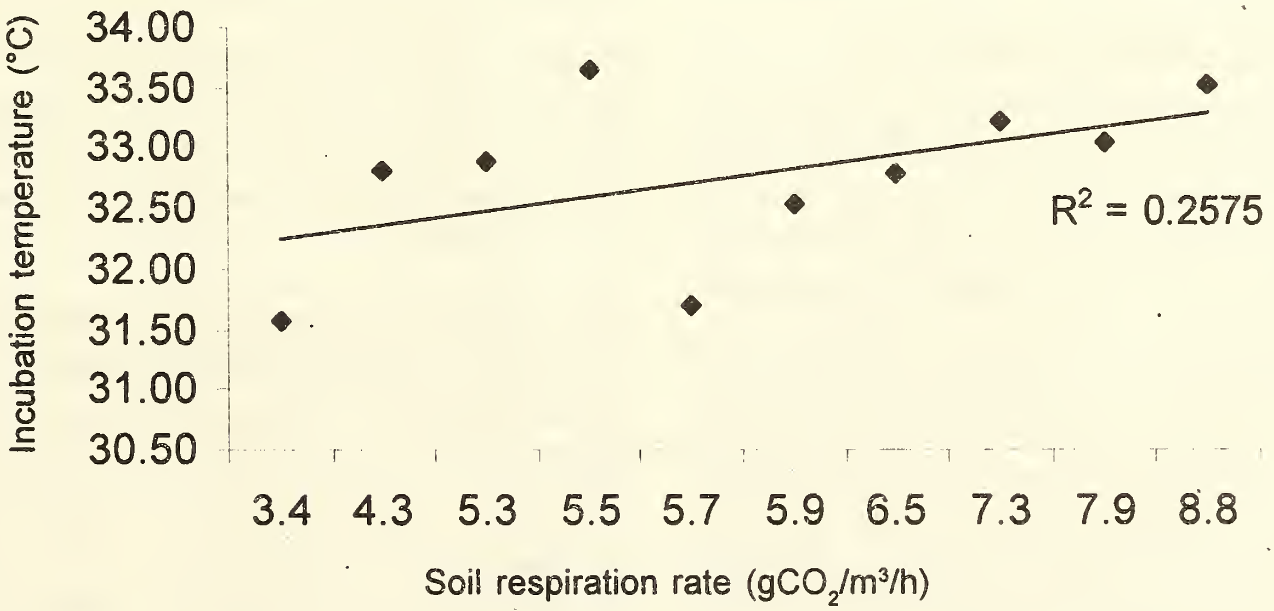


Fig. 4: Effects of microbial activities on the incubation temperature in the mounds of the Nicobar megapode

Egg-laying behaviour of the Nicobar megapode

The egg-laying interval between two consecutive eggs and the clutch size of the Nicobar megapode was estimated from 28 colour-marked birds. The mean egg-laying interval between two consecutive eggs of the Nicobar megapode was 14.91 ±1.43 days (n=11 intervals in 17 eggs). The average number of eggs laid in a mound was 4.5 ±0.6 (n=58) but it significantly varied between the years (Kruskal Wallis H test, c^2 =8.203, df=2, p=0.017). Clutch sizes of the Nicobar megapode varied between one to four eggs per season or year. We collected data on the clutch size of seven colour-marked pairs in 1997 and five in 1998. Of the twelve colour-marked pairs, five pairs laid four eggs per year in one or two mounds and remaining pairs laid two to three eggs in one or two mounds. In general, the average clutch size of the Nicobar megapode was 2.75 eggs (SE 0.35, n=12).

The peak period of the egg-laying was between February and May, during which 86.6% and 84.7% of the eggs were laid in 1996 and 1997 respectively. Egg-laying was not observed during the wet season of our study (September and October of 1997). The total number of eggs laid in all the mounds of the study area in the year 1996, 1997, and 1998, were 112, 124, and 35, respectively.

Incubation mound size and egg-laying

Of the 38 incubation mounds that were active in the study area in 1996, 1997, or 1998, eggs were laid in 35 mounds. Of these, only 10 incubation mounds were used in all the dry seasons between 1996 and 1998 for egg laying.

According to the sizes, mounds were grouped into the four categories, namely very small, small, medium and large mounds. The very small sized incubation mounds (<1 cu. m) had the least number of eggs laid in them (Table 3). Small sized incubation mounds (1-5 cu. m) had an average of 4.05 eggs laid in them, medium sized incubation mounds (5-10 cu. m) contained an average of 5.93 eggs, while large sized incubation mounds had the most number of eggs (Table 3).

Table 3: The mean number of eggs laid in different size classes of mounds throughout the study period

Size of incubation mound	No. of mounds	Eggs laid/ year (±SE)
< 1 cu. m	10	2.3 ±0.77
1.1 – 5 cu. m	7	4.05 ±0.60
5.1 – 10 cu. m	7	5.93 ±1.55
< 10 cu. m	3	6.83 ±1.69

Hatching success

Hatching success was determined in 32 incubation mounds in 1997, where one to five eggs were laid in 13 incubation mounds, six to ten eggs in 6 incubation mounds, and more than ten eggs in 4 incubation mounds. Five of the incubation mounds were not used for egg-laying in 1997, and the number of eggs laid in the remaining four incubation mounds could not be determined. Mean hatching success in the incubation mounds in 1997 was 57.26%. Of the 124 eggs laid in 23 mounds, 10.48% of eggs did not hatch and those eggs were unearthed in the next season; 29.84% eggs disappeared or were predated, and the fate of 2.42% of eggs was not clear (if these eggs successfully hatched then the hatching success was 59.68%).

Small incubation mounds had less number of eggs, while medium sized incubation mounds were used by the birds for more egg-laying (Table 4). However, there was no relationship between the incubation mound size and hatching success (Table 4).

Table 4: Hatching success of eggs in different sizes of incubation mound of the Nicobar megapode in 1997

Size of incubation mound	n	Eggs laid (±SE)	Hatching success % (±SE)
< 1 cu. m	9	1.9 ±0.5	74.1 ±14.5
1.1 – 5 cu. m	7	6.6 ±1.8	52.6 ±8.1
5.1 – 10 cu. m	4	9.5 ±3.1	68.1 ±11.0
> 10 cu. m	3	7.7 ±1.7	59.6 ±7.1

DISCUSSION

Incubation conditions within incubation mounds

Incubation mounds of the megapodes are amongst the largest structures made by any non-colonial animal, and represent the harnessing of the energy produced by microbial respiration (Seymour *et al.* 1986, Jones 1989), and/or solar radiation (Frith 1956, 1959) by concentrating suitable material to provide optimal incubation conditions at about 33-34 °C (Dekker 1992). In some species, microbial respiration and solar radiation may be used sequentially to create incubation conditions (Frith 1956, 1959). Seymour (1985) proposed that heat production and heat loss tends to stabilise mound temperatures at an equilibrium state due to the great thermal inertia of mounds once they cross a certain size and as they maintain adequate moisture content with the regular incorporation of fresh organic material into the mound. This model has gained further support from other studies (Jones 1988, Jones and Birks 1992).

Mound temperatures usually stabilise between 32-35 °C (Jones *et al.* 1995), which is consistent with that of the Nicobar megapode (32.44 °C). Incubation temperatures in mounds show considerable fluctuation, and while the negative effects of these fluctuations on eggs are largely offset by a variable incubation period (Booth 1987), there are strategies to balance both heat loss and gain (Jones 1989, Jones and Birks 1992).

However, the data from the incubation mound of the Nicobar megapode does not fully fit with the assumptions mentioned above by Seymour (1985). Firstly, the size of the incubation mound can vary in height from 10 cm up to 2.1 m and in basal circumference from 7 to 45 m (Sankaran 1995). Secondly, the proportion of organic material in an incubation mound varies due to location of the mound, and the availability of materials around it. And thirdly, the gap in the canopy above the incubation mound varies, resulting in differences in the amount and duration of sunlight falling on it. This might indicate that the heat sources which create suitable incubation conditions within the mound may vary, with some incubation mounds appearing to rely more on sunlight and others on organic decomposition (Sankaran and Sivakumar 1999).

Solar energy, however, probably only optimises the incubation mound temperatures. Though the canopy above an incubation mound was less than the canopy above non-mound areas, direct sunlight fell on the mounds for very short periods, with the result that both ambient temperature and incubation mound surface temperatures were always lower than incubation mound core temperatures. Thus, the role of solar energy appears to be restricted to warming the surface of the incubation mound, whereby dissipation of heat was reduced.

Microbial respiration is the primary source of heat harnessed by most mound building megapodes (Jones *et al.* 1995). A clear relation exists between the incubation temperatures and the organic activity as evidenced from soil respiration in the Nicobar megapode as well. Microbial respiration has a linear relation to the temperature of the incubation mound at deeper layers. However, incubation mounds with higher levels of soil respiration did not necessarily have higher temperatures. Two factors could be responsible for this. Firstly, there might be differences in the amount of heat produced by decomposition due to the kind of vegetative materials added to the incubation mound. Secondly, the rate of heat loss probably differs between incubation mounds, caused by differences in the proportion of surface area to the volume of the incubation mound, or to the amount of moisture content within the incubation mound (Jones *et al.* 1995), or the amount of sunlight or radiation from the beach falling on the mound.

Mound size, egg-laying and hatching success

The optimisation of incubation conditions in large incubation mounds is reflected in an overall trend of a greater number of pairs using such mounds, and consequently, a greater number of eggs being laid in them. However, some small mounds had a greater number of eggs, and some larger mounds had fewer eggs, indicating that size is not the only criterion. The quality of the incubation mound, and the number of pairs using an incubation mound, which appears to be somewhat independent of incubation mound size, are probably other determining factors.

As optimal temperature was consistently present in large mounds, one would expect that eggs in large incubation mounds are more likely to hatch successfully than in smaller incubation mounds. However, hatching success of the Nicobar megapode does not reflect this trend. This study reveals that there was no significant relationship between the incubation mound size and hatching success. Very small and medium sized incubation mounds showed more hatching success than the small (1-5 cu. m) sized ones. The probable reason for the lower hatching success in the small sized incubation mounds (1-5 cu. m; Table 4) was the large number of birds that used them. Greater digging activity and consequently greater exposure of eggs to the atmosphere was a possible factor for lower hatching success. Secondly, more mound activities may attract more predators, especially monitor lizards. About 30% of megapode eggs were predated in 1997, when activities at the mound were also the most. Clutch size of the Nicobar megapode was lower than other mound building megapodes (Jones *et al.* 1995).

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THE SONG OF *NINOX SCUTULATA OBSCURA*

(*With one text-figure*)

Ben King[1]

Key words: *Ninox scutulata*, *Ninox affinis*, sonograms, Andaman and Nicobar Islands

There has been some controversy over the relationship of the two species of *Ninox* owls occurring in the Andaman Islands. Sonograms of the calls of positively identified individuals clarify these relationships.

As *Ninox scutulata obscura* Hume 1873 of the Andaman and Nicobar Islands is almost entirely dark in colour, there has been some uncertainty about its relationship with mainland *Ninox scutulata*. Further complicating the picture is the presence of *Ninox affinis* Beavan 1867 on the Andaman and Nicobar Islands. Superficially, *N. affinis* resembles mainland *N. scutulata* much more than *obscura* does.

Ali and Ripley (1981) do not mention the song of *obscura* in their account of that form. However, in their account of *N. affinis*, A.L. Butler is quoted as saying that the call of *affinis* is "a loud craw, something like a *Glaucidium*'s note and quite different from that of *N. scutulata* in Ceylon (=Sri Lanka), which is a flutey disyllable, as is also that of *obscura*," thus offering an accurate description of the calls of both species. Abdulali (1964) also correctly noted the song of *obscura* as a "loud dysyllabic *coo-ook*."

In March 1991, I had the opportunity to visit North Andaman Island and was able to tape record both *N. scutulata obscura* and *N. affinis*. Sonograms of both are presented in Fig. 1. The left diagrams show frequency plotted with time, showing the upward inflected double note of *N. scutulata* and the downward inflected single note of *affinis*. The right side of the figure is a

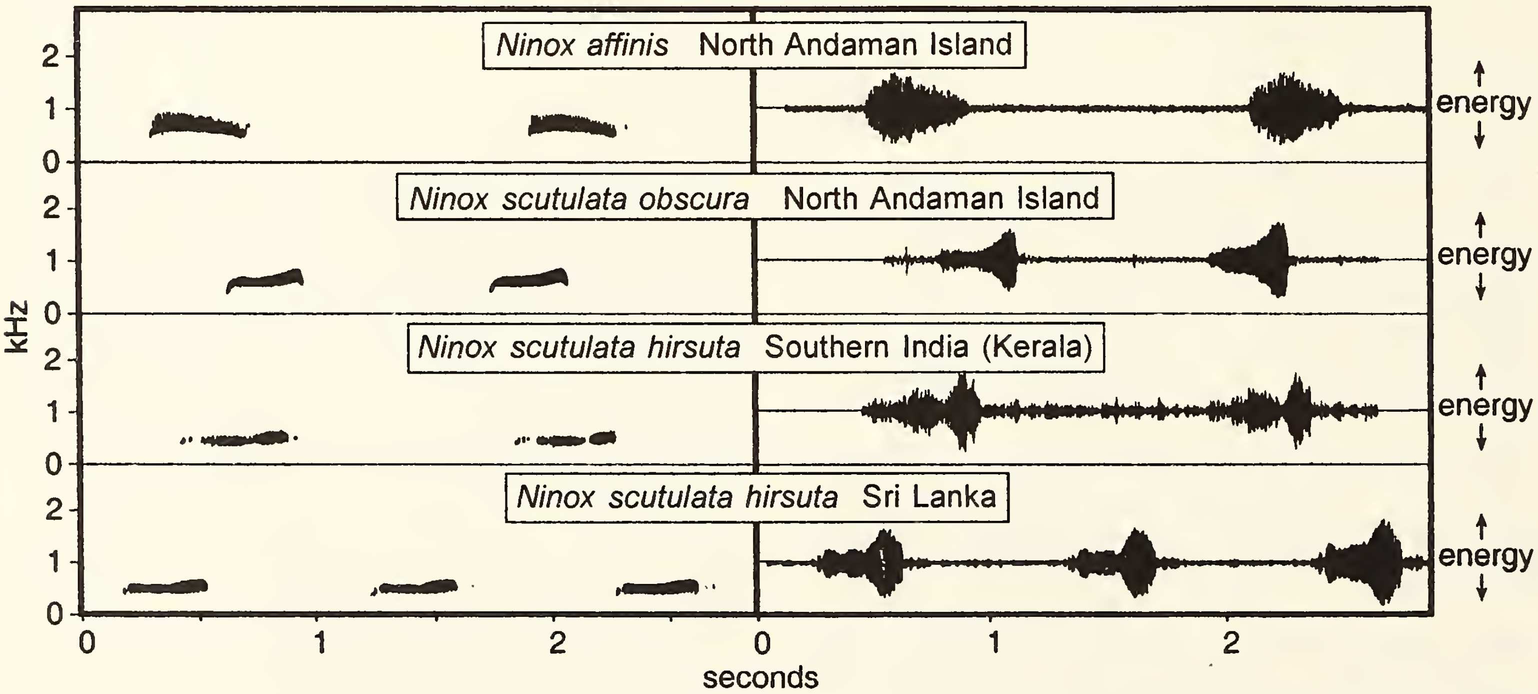

Fig. 1: Song of *Ninox scutulata obscura* of the Andamans compared with songs of *N.s. hirsuta* from Kerala and Sri Lanka, and with the song of *N. affinis* from the Andamans

wave form sonogram showing the amplitude of sound energy emanating from a central axis. The double note of *scutulata* is distinct in *hirsuta* from Kerala and Sri Lanka, but less so in *obscura* in the Andamans. The single note of *affinis* is clearly shown here.

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I was able to observe both species at close range in a powerful flashlight beam, wherein the all-dark underparts of *obscura* and the streaked underparts of *affinis* were conspicuous.

The song of *obscura* is a mellow hollow double note *whoo-wup* with a rising inflection and accent on the second note and is similar to that of *Ninox scutulata hirsuta* of southern India and Sri Lanka. It differs only slightly in having a shorter gap between the two notes.

The song of *affinis* on the other hand, is a mellow raspy single note *woow*. Often two notes are uttered (with a gap between them) as a couplet.

The sonograms show the close relationship of *obscura* with mainland *scutulata* and the distinctness of *affinis*.

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I particularly wish to thank S.A. Hussain for arranging the trip and being a great field companion. Jeff Groth prepared the sonograms. John Fitzpatrick and Greg Budney of the Macaulay Library of Natural Sounds at the Cornell Laboratory of Ornithology provided tape recording equipment and other assistance. All the tape recordings were made by me and will be eventually on deposit at the Macaulay Library of Natural Sounds at the Cornell Laboratory of Ornithology.

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LEARNING ABOUT VOCAL COMMUNICATION IN BIRDS

T.J. Roberts[1]

Key words: Birdsong, recordings, Pakistan, sonograms, song function

Birdsong is of value to observers in identifying and locating unseen species. Modern advances such as magnetic high frequency tape recording and sonograms have led to a greater understanding of the subject. However, there are limitations to interpretation of sonograms. Reaction of birds to playback of songs can help distinguish sibling species and even new species. Birdsong serves varied functions such as in intra-specific recognition, females' selection of mates, spacing out of territories, and in colonial breeding species, mate or chick recognition. Variation in the songs of geographically separated birds of the same species points to the role of learning by imitation in the development of complexity of repertoire in a young bird. The role of voice in intra-specific recognition is particularly critical in the case of cryptic nocturnal species with stereotypic songs. Also significant are flight calls that keep the flock together and alarm calls that warn birds of danger.

As any birdwatcher knows, the quickest way to find out what species are in the vicinity is to learn to recognise their songs and calls. With the great increase worldwide, in studying birds, we have many new tools to familiarise ourselves with the nature and meaning of birdsong. The invention of the lightweight portable tape recorder, the publication of compact disks with collections of recorded birdsong and the development of sonograms (also called spectograms) which show the frequency band of bird calls in a plot against time, have all increased the non-specialist's knowledge of this fascinating aspect of bird behaviour.

During the 1970s and 1980s, I was able to collect recordings of 319 species mostly from Pakistan but also many from India (Roberts 1991), and during these years, being keenly focussed on their calls and song, was stimulated to continue trying to keep up to date with recent research and developments in this field.

As with all biological research, the more we learn, the more questions remain unanswered, and a brief article such as this can do no more than review current aspects, and recall some examples from personal experience.

Firstly, the increasing use of published sonograms in bird books and journals needs to be better understood by the layman and amateur such as this writer (Catchpole and Slater 1995, Slater and Sellar 2000). You cannot differentiate tone or pitch from a two-dimensional graph. A sonogram can clearly show the small dialectical differences between songs of the same species and details of the make up of the song, which would otherwise be undetectable to the human ear. Birds, it is believed from experiments, can detect higher pitched sounds up to 8,000 cycles per second, usually called 8 kHz, well beyond the limited hearing range of humans. Moreover, it is therefore possible to show side by side on a printed page, the sonograms of two or more different birds, for a leisurely and careful comparison that is not possible by actually listening to separate voice recordings. We can easily learn to recognise from the black lines and smudges on a sonograph, the types of phrases or strophes that make up a bird's song repertoire. Twittering shows closely spaced, rather short, vertical black smudges while vehement high-

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pitched calls are shown as longer darker bands in a vertical plane. Also, the louder the note, usually the wider is the black mark in a vertical plane. The sort of calls or phrases that can be verbalised as "beeze" will appear as a broad horizontal band. But again these marks should be interpreted with caution. The rapid ticking calls of some *Bradypterus* warblers can appear very similar to twittering, and one should always look carefully at the vertical graph line showing increasing kHz, as the lower down the scale, the deeper in pitch the call which may otherwise look similar in shape on the sonogram. Research in the development of sonograms and study of birdsong has now stretched over fifty years, and has come a long way from the pioneering studies by Thorpe (1958), who showed that the songs of chaffinches (*Fringilla coelebs*) which appear to be stereotyped and similar within that species, actually vary in small details both between individuals and especially between different regions, revealing the importance of dialectic variation even in species with comparatively consistent stereotyped songs. In recording the social calls of a family group of common babblers (*Turdoides caudatus*) on the western border regions of Balochistan, I found their evening territorial chorusing so different from those in the Punjab plains, as to be at first unrecognisable. I hazarded the opinion (Roberts 1992) that this showed that the population had been geographically isolated for a long period, so much so it they probably would not interact with a family flock from the Indus plains if it could be juxtaposed nearby, because it is known that this very sedentary species, living in tight family groups, maintains its territory against rival groups, by such evening choruses at the roost site. It is likely that this development of local dialects is one of the forces that lead to speciation. In Pakistan many consider the grey-winged blackbird (*Turdus boulboul*) to be the finest songster, a view shared by the great Dr. Sàlim Ali (1973) in his writings. I taped continuous songs in the Murree foothills of Pakistan, showing an unbroken sequence of hundreds of different melodious and dramatic strophes or phrases, especially in the early part of the breeding season (Roberts 1992). A few years later, on encountering a small isolated population of grey-winged blackbirds in a patch of deciduous forest at Mahandri, in Hazara district, I was astonished at the very limited and poor range of their songs. This was proof of what was already known about the importance for juvenile birds to learn their songs by imitation. Research has more recently shown that birds develop and learn the complexities of their full song in the first year of their lives, and thereafter there is no increase in variety or complexity (Dowsett-Lamaire 1979).

What then do we understand of the purpose or functions of birdsong?

Firstly, it forms an essential ingredient in intra-specific species recognition, not only for successful breeding, but in the case of highly colonial breeding species, for the recognition of one's chick, and in the clamour of a large breeding colony, the voice of one's mate. We still do not understand how the Emperor penguin (*Aptenodytes forsteri*) can recognise its offspring, apparently by voice alone, in circumstances where both parents have to be out at sea, food-hunting for prolonged periods, and where the chicks form vast huddled creches, constantly jostling for better positions in the throng. The calls of the parents are, to our ear, comparatively short and raucous and sound remarkably similar. The minute differences in pitch or phrasing are obviously not detectable to the human ear and sonograms have indeed shown that birds can detect such minute differences.

The development of high frequency magnetic recording tape, and the ability to include playback microphones with such portable tape recorders, has opened up a powerful new tool for ornithologists. Since it is only males that have elaborate territorial and mate attracting songs, the playback of recorded song in the vicinity of a certain male species can often result in an intense aggressive or curious reaction. So much so, that this tool of playback and the degree of response by the live bird is used to recognise and distinguish sibling species and even new species (Irwin *et al.* 2001, Collinson 2001). In the view of some conservationists, there is a downside to this practice of searching for possible presence of species by playing their songs when used indiscriminately during the breeding season. However, many reputable wildlife tour operators use this tool with discrimination to enable their clients to get the best chances of viewing shy and elusive birds. The power of such recordings was well demonstrated when KingBird Tours, during an expedition to northwest China, played the calls of that skulking and shy bird, the corn crake (*Crex crex*), and eventually had the excited bird coming out of the tall grass on to an open road and pursuing the human party, calling repeatedly (King 2001).

A second vital function of birdsong, which has long been known, is mate attracting. Studies of the long and complex songs of some passerines have shown that there is a clear correlation between the success of displaying males with the longest songs and their ability to attract females, and this may be an important element in understanding why some species include a huge range of almost perfect imitations of other species' calls in their song repertoire. Dr. Sálim Ali (1972) records mimicry by *Lanius schach* of over 30 different species of birds, as well as realistic imitation of a puppy yelping. Others, including this author (Dowsett-Lemaire 1979, Roberts 1992), have also noted that the mimicry by some songsters included calls of species they could encounter only in their winter migratory territory, not in their breeding grounds. While recording the display of the Isabelline wheatear (*Oenanthe isabellina*) in Baluchistan, this author was intrigued to hear clearly, the imitated flight calls of wood sandpipers (*Tringa glareola*) and red-wattled lapwings (*Vanellus indicus*), both not found on their nesting grounds, as well as such life-like imitations of a shepherd whistling to urge his flock on and a puppy sqealing, that a nearby dog became very excited looking for the source.

Thirdly, song is also used by males to warn off rival males and to define and maintain territorial boundaries, as already discussed under the use of playing back such recordings in the field. While recording the song of the White's mountain or scaly thrush (*Zoothera dauma*) in a wide forested mountain amphitheatre, I was surprised to learn, over several evenings, how many widely spaced song posts were used by this bird, indicating the large area that it hoped to maintain as its breeding territory (Roberts 1992). On another occasion, trying to attract a collared scops-owl (*Otus bakkamoena*) for identification on a dark night, my teenage son was suddenly dive-bombed by the irate bird, to our mutual surprise and fright!

Returning to the importance of voice in intra-specific recognition, this is especially critical in nocturnal species, especially those with cryptic plumage. In our studies on the songs of scops-owls of the *Otus* genus, it soon became apparent that many sibling species which could only be separated with difficulty in the hand, and which had previously been separated only as subspecies, were in fact quite distinct sympatric, non inter-breeding species (Roberts and King 1986). The same holds true to a larger or lesser extent for many of the Caprimulgidae and Acrocephaline warblers, characteristic of skulking lifestyles, in a restricted visual habitat of reed beds.

In a short article of this nature, it is not practicable to discuss the important and varying roles also played by flight, contact and alarm calls. The importance of the continuously uttered contact calls that keep the flock together, to such gregariously foraging birds as the minivets (*Pericrocotus* spp.), as they sometimes erratically search over the forest canopy, will be apparent to any keen birdwatcher. Studies of alarm or warning calls of small passerines have shown that they are rather low pitched and often very similar among different species. Such calls being of low frequency, carry further, and are more difficult to locate direction-wise, thus concealing the location of the alarm giver, and also enabling nearby birds of other species to respond quickly to potential danger (Catchpole and Slater 1995)

The Crane Family with their lifelong pair bonds, longevity, and courtship duetting and dancing have great appeal to many national cultures. When in flight their ringing calls, as everyone knows, carry amazing distances. Dissection of their trachea (windpipe) reveals a convolution, reminiscent of a French horn, a gradually evolved anatomical feature which must partly explain the continuous though precarious survival of this ancient bird family which needs wide open spaces far from rival pairs for nesting, yet can congregate in astonishingly huge flocks during migration. The overhead calls of even the smallest skein of cranes act as a clarion call to any small populations on the ground below.

Lastly, the importance of song in taxonomy is only recently being appreciated. We live in an era of taxonomic turmoil with the recent advances in molecular genetics and DNA sequencing forming powerful tools in examining inter-species relationships, and ultimate phylogenetic relationships are still being disputed. Yet, increasingly, sibling species are first recognised in the field as being distinct and often new species, on the basis of their taped songs and reaction to playback (Alström *et al.* 1992, Collinson 2001). Whilst the wealth of new research is teaching us more about the complexities and meaning of birdsong and calls, we should never lose sight of the aesthetic pleasure we get from being able to pause in our busy life, simply to listen and to enjoy their chorus.

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BIRD SPECIES DIVERSITY ALONG THE HIMALAYA: A COMPARISON OF HIMACHAL PRADESH WITH KASHMIR

(*With two text-figures and two plates*)

Trevor Price[1,2], Jennifer Zee[1], Kartika Jamdar[3] and Nitin Jamdar[3,4]

Key words: Avian diversity, Himachal Pradesh, Kashmir

About 80% of the birds of the Indian subcontinent can be found within the Himalayan region. We studied variation in bird numbers along the Himalaya. There are more than twice as many species in the east than there are in the west. Most of the decline in species numbers from east to west occurs between western Nepal and northern Pakistan, where the trend of the Himalaya follows a more northerly course. We compared the breeding birds of two sanctuaries across this region of steep decline in species numbers, Manali in Himachal Pradesh, whose birds are described for the first time in this paper and Overa in Kashmir (Price and Jamdar 1990, 1991). Differences in species' composition are large, e.g. one-third of the high elevation (*c*. 3,000 - 3,500 m) species were recorded from only one or other sanctuary. Some of the missing species from one or other sanctuary were not a consequence of a range limit between the sanctuaries, but rather a result of a gap in the distribution. Species with patchy distributions included the western tragopan *Tragopan melanocephalus* whose range was historically known to be much more extensive, and the Nepal wren-babbler *Pnoepyga immaculata*. We conclude that there is considerable variation in species composition along the Himalaya and this is being accentuated by local population extinctions.

INTRODUCTION

Large numbers of bird species live in the Himalaya (Meinertzhagen 1928, Inskipp and Inskipp 1985, Martens and Eck 1995). In addition, species composition varies along the Himalaya and there are many more species in the east than in the west (Inskipp and Inskipp 1985). While this pattern is qualitatively known, it has not been quantified, and its underlying cause is not understood. In this paper, we investigate variation in species number along the Himalaya. We use a broad scale comparison based on published species range maps to document general patterns, and then a more detailed comparison of two sites in the Northwest Himalaya (in Himachal Pradesh and Kashmir) where we have conducted fieldwork over the past 15 years. We investigate how total species numbers change along the Himalaya and the extent to which species composition varies between different localities.

Although the Himalayan range is often considered to run from east to west, particularly from Nepal west it follows a southeast to northwest trend, and spans *c*. 5 degrees latitude from western Nepal to Srinagar in Kashmir (Plate 1, Fig. A and Plate 2, Fig. B). As we will show, total species numbers along the Himalaya decline mostly in association with this latitudinal gradient, rather than with longitude. The two sites we worked at (Manali Sanctuary in Himachal Pradesh and Overa Sanctuary in Kashmir) are located in a region where there is a steep decline in species numbers. The data from Overa have been previously published (Price and Jamdar 1990, 1991), but the data from Manali are presented here for the first time. Therefore, a second purpose of this paper is to document the breeding birds (including range extensions and altitudinal distributions) for Manali Sanctuary for which there is no previously published ornithological survey.

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Price, Trevor *et al.*: Map PLATE 1

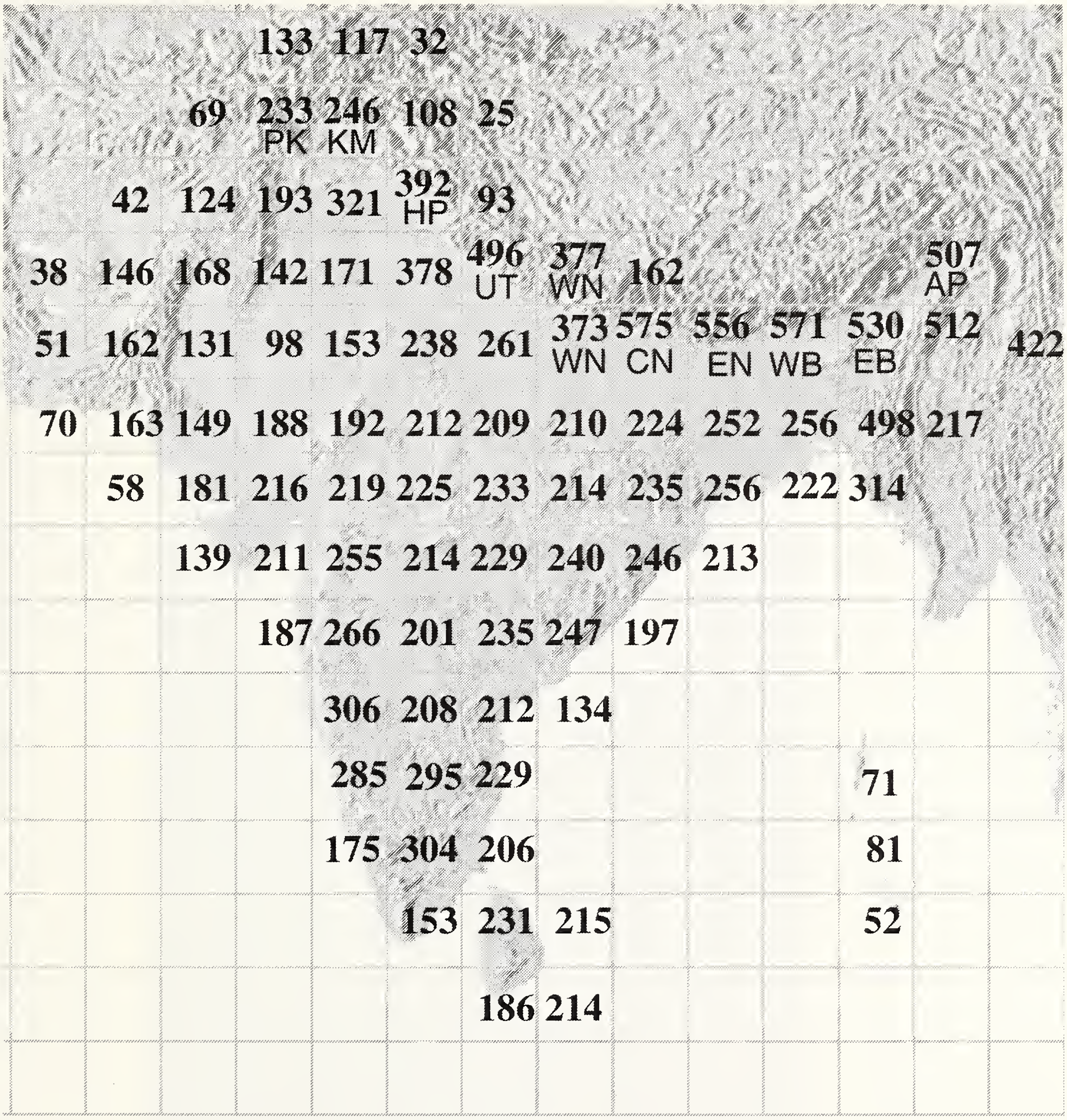
133 117 32
69 233 PK 246 KM 108 25
42 124 193 321 392 HP 93
38 146 168 142 171 378 496 UT 377 WN 162 507 AP
51 162 131 98 153 238 261 373 WN 575 CN 556 EN 571 WB 530 EB 512 422
70 163 149 188 192 212 209 210 224 252 256 498 217
58 181 216 219 225 233 214 235 256 222 314
139 211 255 214 229 240 246 213
187 266 201 235 247 197
306 208 212 134
285 295 229 71
175 304 206 81
153 231 215 52
186 214

Fig. A: Numbers of breeding species in 250 x 250 km squares across the Indian subcontinent, based on Grimmett *et al.* (1999a)

Squares with letter symbols are those subject to more detailed analysis in the text and in Fig. 1. Symbols indicate rough locations: PK – northern Pakistan, KM – Kashmir, HP – Himachal Pradesh, UT – Uttaranchal, WN – western Nepal (two squares are included because neither alone covers the complete altitudinal range), CN – Central Nepal, EN – Eastern Nepal, WB – Western Bhutan, EB – Eastern Bhutan, AP – Arunachal Pradesh.

Price, Trevor *et al.*: Map

PLATE 2

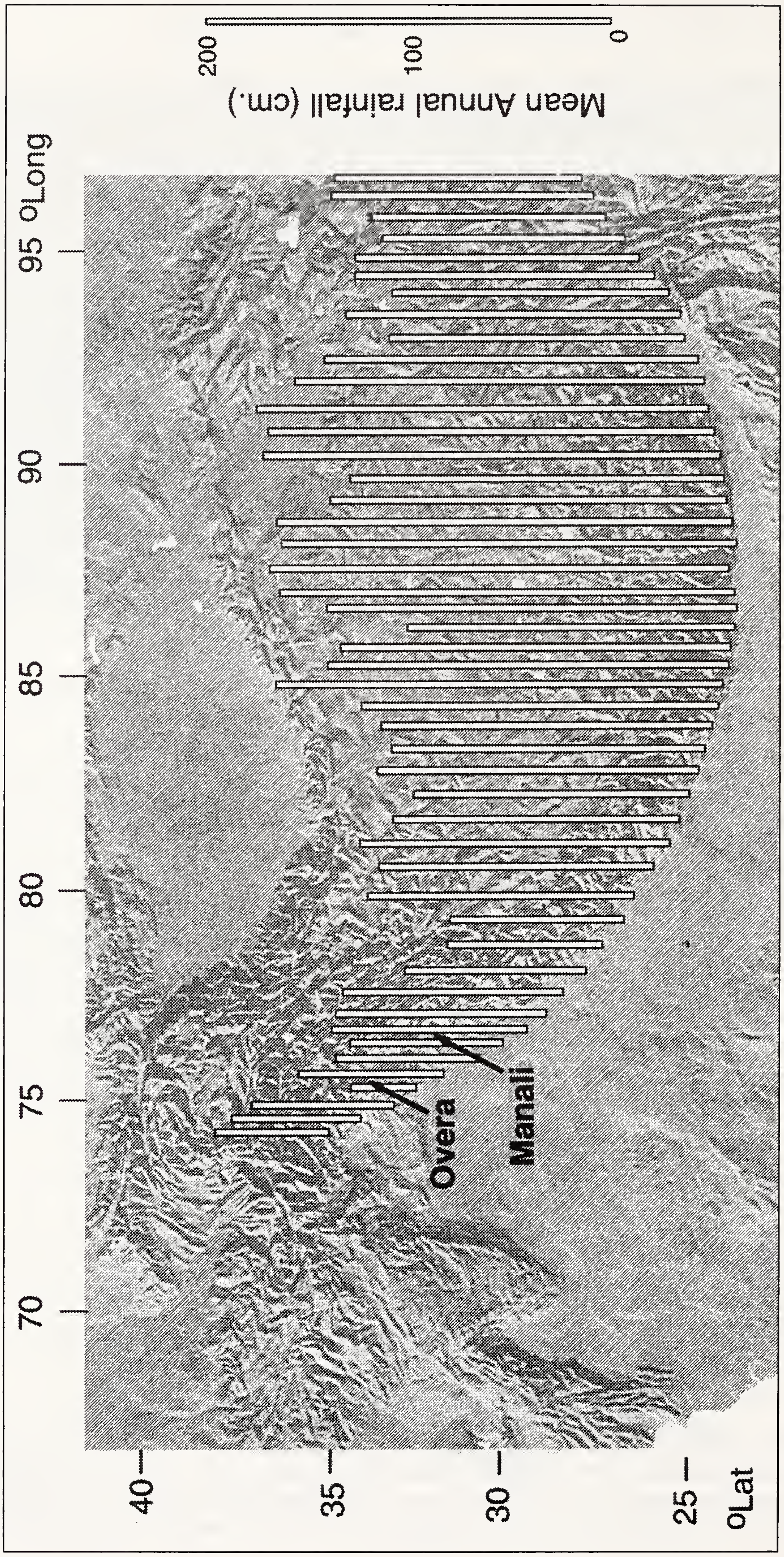
Mean Annual rainfall (cm.)
200
100
0
70
75
80
85
90
95 °Long
40
35
30
25
°Lat
Overa
Manali

Fig. B: Locations of the two long-term study sites and annual precipitation estimated for half-degree coordinates along the Himalaya (see New *et al.* 1999, 2000)

METHODS

Broadscale comparisons

Taxonomy and nomenclature throughout this paper follow Sibley and Monroe (1990). We used a field guide (Grimmett *et al.* 1999a) to estimate the numbers of breeding bird species at different locations in the Indian subcontinent. We excluded species that were primarily pelagic, leaving us with a dataset of 976 breeding species that we considered to be dependent on land or freshwater. The species used and the data collected are available at http://www.biology.ucsd.edu/tprice. Following the methods of Fjeldså (1994), we overlaid a transparent grid of 14 squares x 14 squares on each map in the field guide. Each square is approximately 250 km x 250 km. Plate 1, Fig. A shows the grid with the approximate position of the squares (position is approximate because the map projection used by Grimmett *et al.* (1999a) differs from the one used here). Then we recorded the presence or absence of the species in each square. With this information, we were able to calculate the number of breeding species in each square, and the extent to which different squares share species. We also used Ali and Ripley (1987) and Grimmett *et al.* (1999b) to assess the altitudinal bands in which a species is found (divided into 1,000 m intervals). For many species altitudinal distributions vary considerably along the Himalaya (Martens and Eck 1995). We ignored this spatial variation, simply recording minimum and maximum elevations as far as are known.

We obtained climate data described in New *et al.* (1999, 2000) and available at http://mercury.ornl.gov/ornldaac. This dataset provides (extrapolated) mean monthly averages for eleven climate variables at 0.5° latitude and longitude intervals across the whole land surface of the world. We based our analysis on measurements made between 1901 and 1960. We extracted mean annual precipitation for points along the Himalaya. We also used measurements of climate reported for individual meteorological stations in the Himalaya (Anon. 1967).

Field studies

The two study sites are Overa (33° 80' N, 75° 40' E) near Pahalgam in Kashmir, and Manali (32° 20' N, 77° 20' E) in Himachal Pradesh (Plate 2, Fig. B), 250 km to the southeast of Overa.

Overa Sanctuary (33 sq. km) forms the watershed to a small valley running approximately northwest to southeast (Price and Jamdar 1990). The elevation spans from about 2,400 m to above the treeline. We were camped at sites at approximately 2,400 m or 3,300 m from May to July in each of the three years from 1985-1987, as described in Price and Jamdar (1990, 1991). Either TP or NJ returned to Overa for a period of 1-2 months (May or May-June) in each of the subsequent four years, from 1988-1991. Our latest observations confirmed the previous findings, with a few additions reported in Appendix I.

Manali Sanctuary (32 sq. km) is a watershed similar in size to Overa, but the main river runs west to east (Singh *et al.* 1990). The altitudinal range is from *c.* 2,000 m (just outside the town of Manali) to above the treeline. We spent the following periods in Manali Sanctuary, camped at 3,100 m: May-June 1994 (TP), early May 1995 (TP), late June 1996 (TP), late June - early July 1997 (TP), May-June 2001 (TP, NJ, KJ), and May 2002 (NJ, KJ).

We recorded all the birds observed in a daily logbook. We estimated bird abundance using point censuses and mistnet capture rates, but found the most satisfactory measure to be simply the fraction of days a species was observed, which is reported here. This measure is weakly correlated with mistnet captures [correlation coefficient ≈ 0.5 in Overa (Price and Jamdar 1990)].

We made a special effort to assess altitudinal distributions. These are poorly known for the Himalaya, partly because they can vary greatly from place to place (Martens and Eck 1995), and partly because it has been difficult to separate breeding from winter and migratory records (e.g. Inskipp *et al.* 2000).

Altitudinal distributions must always be approximate. Firstly, they vary even within a valley. For example, south-facing slopes in Manali have much more extensive kharsu oak *Quercus semecarpifolia*, whereas north-facing slopes have more extensive fir *Abies pindrow*, and bird species associated with these habitats have different altitudinal distributions on each side of the valley. In Manali, we worked on a north-facing slope. Secondly, individual singing males may occupy territories far out of the normal range. This is particularly true for estimates of lower boundaries, as occasional males may remain singing and unmated at low elevations until late in the season (see for example, bimodal distribution of *Phylloscopus reguloides* in Fig. 2, probably as a result of 1 or 2 singing males at low elevations, where the species was not generally observed), but may also apply to upper boundaries (for example, a lone *Cettia fortipes* established a territory at c. 3,000 m in Overa). Thirdly, rare species are easily overlooked. In Overa, we attempted to estimate lower and upper altitudinal bounds for each species, based on localities where it appeared that several pairs were likely to be breeding. We based our estimates on repeated observations of birds throughout the 3 years of our initial study, and found these to be upheld in four subsequent seasons. In Manali, we conducted censuses along the entire altitudinal gradient by halting for 2 minutes at intervals of every 25 m altitude (measured using an altimeter), and recording all birds seen and heard (this was conducted over a period of 2-3 mornings from 0600-0900 hrs in each of the three years 1996, 1997 and 2001). We then listed the altitudinal distributions of all species from these censuses, and evaluated the list on a species by species basis in the field in May 2002. Despite all the caveats associated with estimates of altitudinal distributions, species differ considerably in where they live on the mountain, and our estimates are consistent between years.

During the course of the altitudinal census at Manali, we also recorded all tree species within an approximate 8 m radius of the census point.

RESULTS

Broad patterns

The number of species in each square across the Indian subcontinent is shown in Plate 1, Fig. A. Results confirm that the Himalaya harbours a large number of species. Indeed, one 250 km x 250 km square in central Nepal contains 575 species, or 60% of all the land and freshwater species breeding in the Indian subcontinent (including the Andaman and Nicobar Islands) and almost twice the maximum diversity recorded from a square in peninsular India. We combined results from 11 squares running the length of the Himalaya from Pakistan to Arunachal Pradesh (see squares with letter symbols in Plate 1, Fig. A). These 11 squares contain a total of 783 species or 80% of all the species found on the Indian subcontinent. This partly reflects the great range of climate regimes, from tropical to temperate, and hence diversity of habitats. For example, 154 (20%) of the 783 Himalayan species breed entirely above 2,000 m. An additional 249 species (32%) are found breeding above 2,000 m somewhere in their geographical range, as well as at lower elevations. The other species occur at lower altitudes, including the plains of India.

There are many more species in the east than in the west. Across the 11 squares running the length of the Himalaya, the easternmost, in Arunachal Pradesh, contains more than twice the number of species of the westernmost square, in Pakistan (507 vs 233 species). The decrease in species number is mainly from Uttaranchal to northern Pakistan, i.e. where there is a substantial south-north as well as east-west trend of the Himalaya. The square including Uttaranchal contains almost 500 species, similar to the square in Arunachal Pradesh.

The steep decline in species numbers across the Northwest Himalaya is associated with a decline in precipitation (Plate 2, Fig. B). In Pakistan, the lower reaches of the Himalaya are very dry and semi-desert. In comparison with Nepal, northern Pakistan has much less monsoon rainfall, more winter precipitation and colder winters (Stainton and Polunin 1984).

Superimposed on changes in total species number is species turnover. 116 species occur in both the westernmost and easternmost squares, i.e. Pakistan (PK) and Arunachal Pradesh (AP), implying that 50% of all the species in the Pakistan Himalaya extend their range throughout the Himalaya. There are many more species in Arunachal, and hence a smaller fraction (23%) of these species extend west to Pakistan. Among species recorded breeding above 2,000 m, 63 species range throughout the Himalaya, which is 43% of the Pakistan total (26% of the Arunachal total).

In Fig. 1, we have plotted the turnover between adjacent squares along the Himalaya. This plot is for all species recorded breeding above 2,000 m altitude somewhere in their geographical range, but the patterns are similar if all species are included. The histograms give the fraction of species in a square that have western or eastern range limits in that square. For example, 30% of the species in the square KM are not found in the square PK whereas 15% of the species in the square KM are not found in the square HP.

Typically about 10% of all species in a square do not extend to the neighbouring square, and patterns of turnover are not strikingly different at different points along the Himalaya or to the east or west. The main exceptions are the squares KM and HP which have a high fraction of species (>30%) that do not extend their ranges to the northwest. Thus, even though some species are confined to the northwest, the southeast to northwest latitudinal gradient in species numbers reflects the fact that larger numbers of southeastern species fail to extend their ranges northwest.

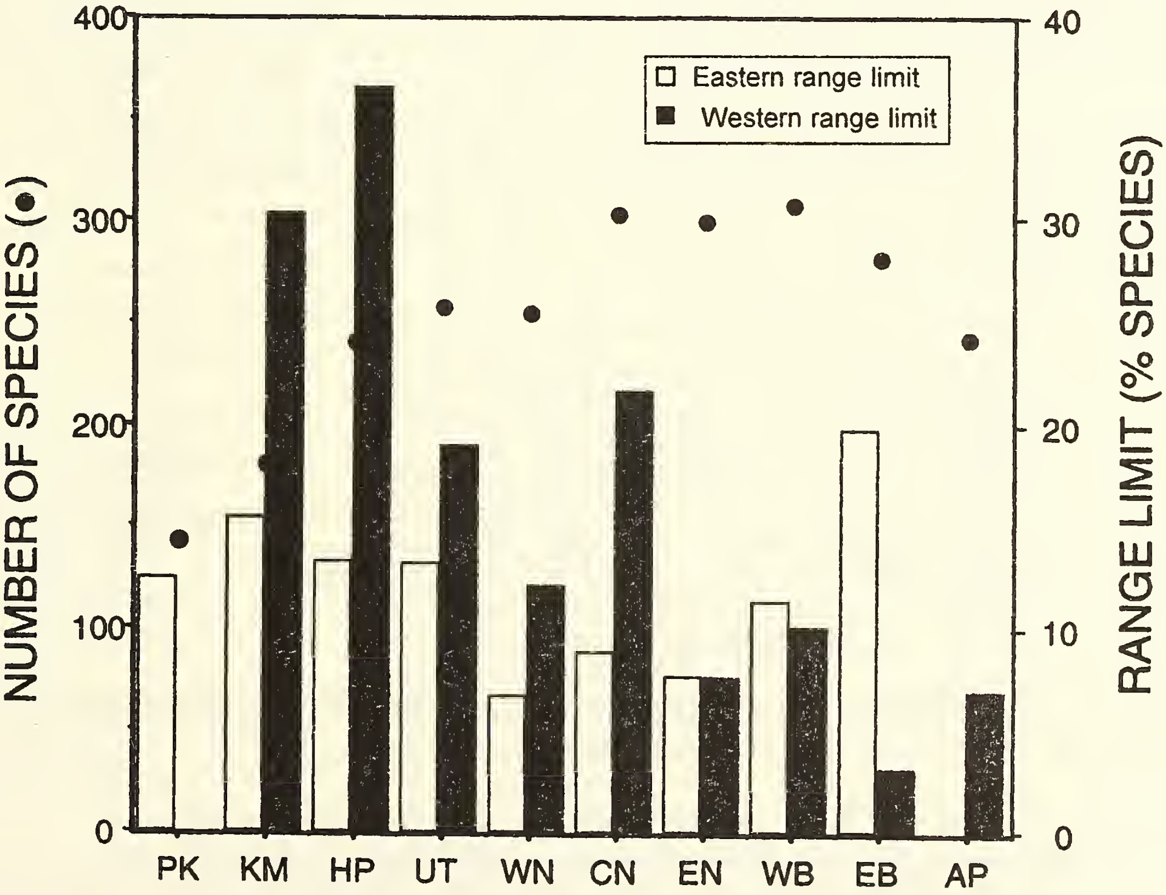

Fig. 1: Species turnover along the Himalaya.
Letter symbols refer to squares indicated in Plate 1, Fig. A, with the two WN squares combined

Himachal Pradesh vs Kashmir

We now investigate the pattern of high species turnover along the Northwestern Himalaya by comparing Manali (Himachal Pradesh) and Overa (Kashmir) Sanctuaries.

Vegetation and climate: The altitudinal distributions of the major tree species for the north-facing slope in Manali are shown in Fig. 2 (for similar data on Overa, see Price and Jamdar 1990, and Price 1991). The vegetation at Manali differs from that at Overa in several ways. Most strikingly, kharsu oak is common in Manali, but absent in Overa (Price and Jamdar 1990). Rhododendron is much more abundant in Manali than in Overa. Juniper, at least in the area where we worked, is much less common in Manali than in Overa. Among tree species held in common, maple *Acer* spp., fir *Abies* spp., pine *Pinus wallichiana*, spruce *Picea smithiana* and birch *Betula utilis* have similar altitudinal distributions in the two sanctuaries.

We do not have comparable climate

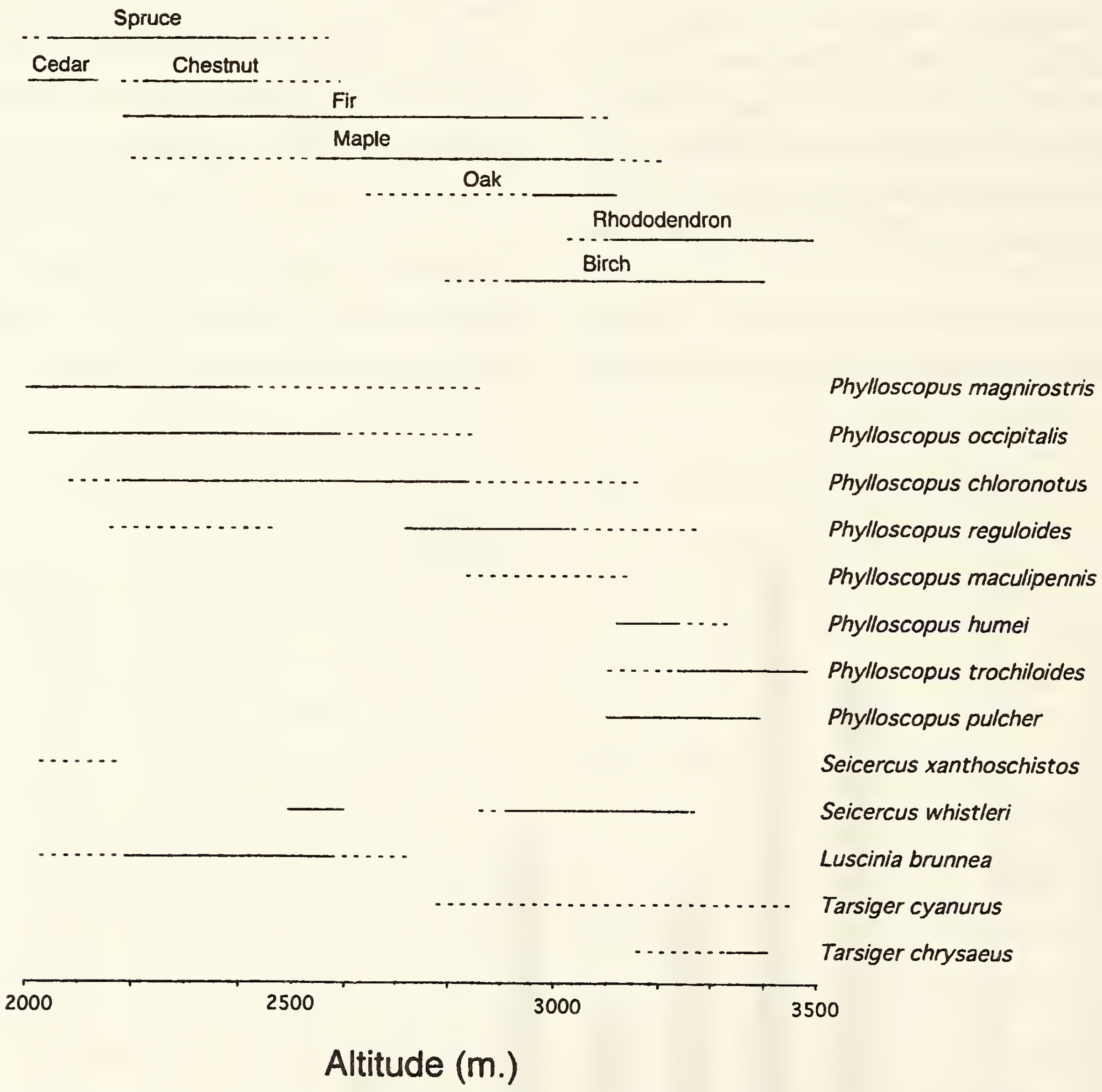

Fig. 2: Distributions of the major tree species along the Manali transect (top) and census records for species of four common bird genera conducted on June 3-5, 1997

Top: ———— = 2 or more individuals recorded within an approximately 8 m radius.
·········· = the extreme records for the species as observed in the 8 m radius.
Bottom: ———— = range over which more than one individual was recorded at each census point.
·········· = the range over which one individual was recorded.
Two minutes were spent at altitudinal intervals of 25 m along the transect, early in the morning.

measurements from Overa and Manali, partly because they were studied over different years and the climate may have been changing: snow disappeared from our camp in Manali approximately one month earlier in each year of 2001-2002 than in each year of 1994-1997 (see also Vedwan and Rhoades 2001). Nevertheless, Manali is probably wetter (Plate 2, Fig. B) and warmer than Overa. To assess this indirectly, we compared climate records for Shimla, Himachal Pradesh (31°N, 77°E) with Srinagar, Kashmir (34°N, 75.5°E), based on 30 years of data (1931-1960; Anon. 1967). Although Shimla is 700 m higher, it has warmer springs (average minimum temperature in May in Shimla is 4 °C higher than in Srinagar) and almost three times the annual rainfall of Srinagar.

Birds of Manali Sanctuary: We recorded a total of 137 species in or near Manali Sanctuary. The data are summarised in four exclusive lists. In Table 1, we present the 81 species encountered above about 2,800 m (higher elevations) in at least two different years with altitudinal distribution and estimates of abundance. Table 2 lists common breeding species in the forests below 2,500 m, with altitudinal distribution. These tables are separated because we spent little time at the lower altitudes, have less quantitative data, and may well have overlooked some species. Appendix II refers to additional species that have been recorded rarely in Manali Sanctuary and Appendix III additional species that primarily breed along the lower boundary of Manali Sanctuary in more open habitat.

In Fig. 2 we show altitudinal distributions based on a single census for common species belonging to four genera. Some species appear to be tightly associated with particular habitats, such as *Phylloscopus humei* with birch (Price and Jamdar 1991). Two species are particularly noteworthy. The first, *Seicercus whistleri*, appears to have a disjunct altitudinal distribution (Fig. 2). This was noted further east in the Himalaya by Alström and Olsson (1999) and Martens *et al.* (1999) who described the lower elevation population as a separate species (*Seicercus burkii*); the upper population is now classified as *Seicercus whistleri*; (see also Alström and Olsson 2000). The possibility that both species are present in Manali needs to be investigated. Secondly, there is a breeding population of the Nepal wren-

Table 2: Common forest bird species in the lower part of Manali Sanctuary that do not extend to higher elevations*

Common name	Latin name	Altitudinal distributions (in m)	
		Low	High
[2]Great barbet	*Megalaima virens*	2,200	2,275
[2]Ashy drongo	*Dicrurus leucophaeus*	2,075	2,150
[1]Blue-headed rock-thrush	*Monticola cinclorhynchus*	2,100	2,175
[2]Grey-winged blackbird	*Turdus boulboul*	1,975	2,075
[1]Rusty-tailed flycatcher	*Muscicapa ruficauda*	-	2,240
[1]Verditer flycatcher	*Eumyias thalassina*	2,000	2,450
[2]Grey-headed flycatcher	*Culicicapa ceylonensis*	2,280	2,575
[1]Green-backed tit	*Parus monticolus*	1,975	2,500
[1]Black bulbul	*Hypsipetes leucocephalus*	2,150	2,450
[2]Grey-hooded flycatcher-warbler	*Seicercus xanthoschistos*	2,050	2,150
Nepal wren-babbler	*Pnoepyga immaculata*	2,300	2,600
Yellow-naped yuhina	*Yuhina flavicollis*	2,175	2,375

[1]Present also in Overa. *Muscicapa ruficauda* is much more common in Overa than Manali.
[2]These species were not recorded in Overa, but are common elsewhere in Kashmir and their absence may reflect the absence of forest habitat below 2,400 m in Overa.
*For additional common species that extend into Manali town, see Appendix III.

Table 1: Common species found above 2,500 m in Manali Sanctuary
Comparative information for Overa is from Table 4 of Price and Jamdar (1990)

Common name	Latin name	Abundance		Altitudinal distributions (in m)			
		[1]Manali	*Overa	Manali		Overa	
				Low	High	Low	High
Western tragopan	*Tragopan melanocephalus*	26	[2]A.	3,100	3,100	-	-
Koklass pheasant	*Pucrasia macrolopha*	63	25	2,360	3,300	2,400	3,200
Impeyan monal	*Lophophorus impejanus*	79	47	2,725	3,250	3,000	3,500
Himalayan pied woodpecker	*Dendrocopos himalayensis*	38	22	2,575	3,100	2,400	3,300
Large scaly-bellied green woodpecker	*Picus squamatus*	25	7	2,430	3,100	2,400	3,200
Common cuckoo	*Cuculus canorus*	77	49	2,090	3,100	2,400	3,200
Lesser cuckoo	*Cuculus poliocephalus*	68	53	1,975	2,900	3,000	3,700
Himalayan swiftlet	*Collocalia brevirostris*	31	[4]Not seen	-	-	-	-
Pacific swift	*Apus pacificus*	7	1	-	-	-	-
Tawny wood-owl	*Strix aluco*	5	32		3,100	2,400	3,400
Collared owlet	*Glaucidium brodiei*	4	10	2,300	2,800	2,400	3,400
Oriental turtle-dove	*Streptopelia orientalis*	26	34	1,975	3,125	2,400	3,200
Eurasian woodcock	*Scolopax rusticola*	70	54	3,100	3,250	3,000	3,400
Bearded vulture	*Gypaetus barbatus*	12	45	-	-	-	-
Himalayan griffon	*Gyps himalayensis*	35	66	-	-	-	-
Eurasian sparrowhawk	*Accipiter nisus*	14	13	2,000	3100	2,400	3,300
Buzzard sp.	*Buteo* sp.	1	47	-	-	-	-
Golden eagle	*Aquila chrysaetos*	13	23	-	-	-	-
Booted eagle	*Hieraaetus pennatus*	7	2	-	-	-	-
Common kestrel	*Falco tinnunculus*	4	32	-	-		3,300
Spotted nutcracker	*Nucifraga caryocatactes*	65	75	2,800	3,100	3,100	3,500
Red-billed chough	*Pyrrhocorax pyrrhocorax*	13	15	-	-	-	3,600
Jungle crow	*Corvus macrorhynchos*	100	91	1,975	3,200	2400	3,600
Long-tailed minivet	*Pericrocotus ethologus*	65	20	1,975	3,275	2,400	3,300
Chestnut-bellied rock-thrush	*Monticola rufiventris*	48	4	3,100	3,100	3,200	3,400
Blue whistling-thrush	*Myiophonus caeruleus*	56	57	1,975	3,125	2,400	3,300
Plain-backed thrush	*Zoothera mollissima*	32	9	3,155	3,425	3,400	3,700
Scaly thrush	*Zoothera dauma*	71	19	3,100	3,100	3,000	3,200
White-collared blackbird	*Turdus albocinctus*	98	Abs.	2,700	3,425	-	-
Eurasian blackbird	*Turdus merula*	1	10	3,850	3,850	3,500	3,700
Mistle thrush	*Turdus viscivorus*	6	[2]Abs.	3,130	3,450	-	-
Yellow-bellied fantail-flycatcher	*Rhipidura hypoxantha*	100	Abs.	3,100	3,300	-	-
Sooty flycatcher	*Muscicapa sibirica*	29	31	2,600	3,240	2,400	3,300
Orange-gorgeted flycatcher	*Ficedula strophiata*	94	Abs.	2,500	3,250	-	-
Ultramarine flycatcher	*Ficedula superciliaris*	33	24	1,975	3,125	2,400	3,300
Slaty-blue flycatcher	*Ficedula tricolor*	46	56	2,750	3,375	2,400	3,300
Indian blue robin	*Luscinia brunnea*	63	42	1,995	3,425	2,400	3,400
Orange-flanked bush robin	*Tarsiger cyanurus*	100	97	2,725	3,525	3,000	3,500
Golden bush-robin	*Tarsiger chrysaeus*	69	[2]Abs.	3,140	3,475	-	-
Blue-fronted redstart	*Phoenicurus frontalis*	8	28	3,150	3,940	-	3,400
White-capped redstart	*Chaimarrornis leucocephalus*	2	13	3,200	3,200	2,800	3,100
White-bellied redstart	*Hodgsonius phaenicuroides*	2	23	3,100	3,100	3,200	3,500
White-cheeked nuthatch	*Sitta leucopsis*	42	29	2,680	3,100	2,400	3,300
[5]Bar-tailed treecreeper	*Certhia himalayana*	62	1	1,975	3,250	2,400	3,200
[5]Eurasian treecreeper	*Certhia familiaris*	40	65	3,100	3,210	3,300	3,500

Table 1: Common species found above 2,500 m in Manali Sanctuary
Comparative information for Overa is from Table 4 of Price and Jamdar (1990) *(contd.)*

Common name	Latin name	Abundance		Altitudinal distributions (in m)			
		[1]Manali	*Overa	Manali		Overa	
				Low	High	Low	High
Winter wren	*Troglodytes troglodytes*	62	95	3,100	3,375	3,000	3,700
Fire-capped tit	*Cephalopyrus flammiceps*	10	16	2,490	3,100	2,400	3,300
Rufous-bellied crested tit	*Parus rubidiventris*	90	6	3,050	3,300	3,300	3,500
Spot-winged crested tit	*Parus melanolophus*	94	89	2,175	3,325	2,400	3,300
Brown crested tit	*Parus dichrous*	24	Abs	3,100	3,160		
White-throated tit	*Aegithalos niveogularis*	23	41	3,240	3,365	3,200	3,500
Northern house martin	*Delichon urbica*	48	48	3,100	3,500		3,500
Goldcrest	*Regulus regulus*	51	21	2,150	3,275	2,400	3,300
Chestnut-headed tesia	*Tesia castaneocoronata*	79	Abs.	2,300	3,260		
Aberrant bush-warbler	*Cettia flavolivacea*	24	Abs.	3,230	3,230		
Grey-sided bush-warbler	*Cettia brunnifrons*	44	[2]Abs.	3,230	3,230		
Spotted bush-warbler	*Bradypterus thoracicus*	35	Abs.	3,100	3,730		
Orange-barred leaf-warbler	*Phylloscopus pulcher*	100	70	3,050	3,475	3,300	3500
Grey-faced leaf-warbler	*Phylloscopus maculipennis*	52	Abs.	2,800	3,230		
Lemon-rumped warbler	*Phylloscopus chloronotus*	100	77	2,150	3,300	2,400	3,300
Hume's warbler	*Phylloscopus humei*	100	97	2,900	3,430	2,400	3,500
Greenish leaf-warbler	*Phylloscopus trochiloides*	73	62	3,100	3,550	3,300	3,500
Large-billed leaf-warbler	*Phylloscopus magnirostris*	80	54	2,175	3,025	2,400	3,500
Western crowned warbler	*Phylloscopus occipitalis*	8	91	1,975	2,900	2,400	3,300
Blyth's leaf-warbler	*Phylloscopus reguloides*	100	Abs.	2,625	3,250		
[3]Gold-spectacled flycatcher-warbler	*Seicercus whistleri*	100	1	2,500	3,275		
Variegated laughingthrush	*Garrulax variegatus*	92	84	2,325	3,500	2,400	3,500
Red-headed laughingthrush	*Garrulax erythrocephalus*	10	Abs.	3,200	3,220		
Greater scaly-breasted wren-babbler	*Pnoepyga albiventer*	90	Abs.	2,785	3,350		
Bar-throated minla	*Minla strigula*	100	Abs.	2,725	3,450		
Oriental tree pipit	*Anthus hodgsoni*	83	Abs.	3,100	3,485		
Rosy pipit	*Anthus roseatus*	11	16	3,350	4,060	3,500	
Rufous-breasted accentor	*Prunella strophiata*	49	89	3,140	3,425	3,200	3,700
Hodgson's mountain-finch	*Leucosticte nemoricola*	17	36	3,025	3,500	3,500	
Spectacled finch	*Callacanthis burtoni*	36	5	2,580	3,140	2,800	3,700
Dark-breasted rosefinch	*Carpodacus nipalensis*	58	1	3,150	3,700		
Pink-browed rosefinch	*Carpodacus rodochrous*	71	77	3,225	3,375	2,400	3,700
Red-headed bullfinch	*Pyrrhula erythrocephala*	38	Abs.	2,930	3,250		
Collared grosbeak	*Mycerobas affinis*	1	Abs.	3,100	3,275		
Black-and-yellow grosbeak	*Mycerobas icterioides*	38	83	2,200	3,155	2,400	3,700
Spotted-winged grosbeak	*Mycerobas melanozanthos*	14	[2]Abs.	2,100	3,100		

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[1] Proportion of days observed when camped at 3,100 m. Based on n = 84 days; 34 days in June/July 1996 and 50 days in May/June 2001.

* Proportion of days observed when camped at 3,300 m (n=224 days in 1985-1987).

[2] Although absent from Overa the species has been recorded as breeding (rarely) in Pakistan (Roberts 1991, 1992)

[3] A single singing male present at Overa in several years.

[4] We did not observe this species as we paid little attention to the swifts, nevertheless it may have been present at Overa, which is close to its range limit.

[5] We did not always distinguish between *Certhia himalayana* and *Certhia familiaris*.

babbler *Pnoepyga immaculata* between *c.* 2,300 m and 2,600 m in the chestnut-spruce-fir woods just above the entrance to the Sanctuary (mostly between 2,300 m and 2,450 m). This species was first described in 1991 (Martens and Eck 1991) and previously only recorded from Nepal. An individual was captured and examined in the hand on May 22, 2001 (wing-length 55 mm, weight 15 g).

Comparison of Manali with Overa: In our study, Manali and Overa can be best compared in the composition of higher elevation species (*c.* 3,000 m - 3,500 m), the habitat being less disturbed, and because we spent much more time at these elevations. For Manali this includes all 81 species in Table 1. There are an estimated 70 common species at Overa at these elevations (see Table 4 in Price and Jamdar 1990).

Twenty-one species are present on the Manali higher elevation list but not in Overa, and 11 species are present on the Overa higher elevation list but not in Manali. Fifty-nine species are included in the lists from both Manali and Overa. Thus 64% of the total number of species in the two sanctuaries combined are found in both sanctuaries and 36% are found in one or other sanctuary.

High elevation Manali species missing from Overa: Of the 21 species present at high elevations in Manali and not in Overa, 5 have been recorded breeding in northern Pakistan (Roberts 1991, 1992). Apart from *Tarsiger chrysaeus*, the remaining 4 (see Table 1) are rare in Manali and may occasionally occur in Overa but may have been overlooked. However, they may also reflect a genuinely patchy distribution, perhaps due to recent extinctions. *Tragopan melanocephalus* is one such example: we never recorded the species in Overa, but there is a small breeding population in Pakistan (Roberts 1991).

One species, *Collocalia brevirostris*, has its range limit in Kashmir, but may have been present in Overa and been overlooked by us. A general feature of many of the species absent or rare in Overa is that they are very common in Manali. Six of them were among the 15 that we recorded on more than 90% of the days (Table 1). For example, *Minla strigula* and *Rhipidura hypoxantha* are two of the commonest species at Manali, but they have never been recorded breeding as far west as Overa. Causes of the absence of these and most of the other species are not understood. It is notable that several ground and bush foraging insectivores that are common in Manali are missing from Overa (*Anthus hodgsoni, Pnoepyga immaculata, Tesia castaneocoronata, Cettia flavolivacea, Bradypterus thoracicus*).

The absence of two species from Overa (*Turdus albocinctus* and *Pyrrhula erythrocephala*) is associated with the presence of an ecologically similar species in similar habitat there (compare Table 1 with Table 3). *Turdus albocinctus* is replaced by *Turdus rubrocanus* in Overa. In 1996, a pair of *T. rubrocanus* was found breeding in Manali and males of the two species were observed chasing each other. Both these species have similar songs and may mutually exclude each other. Note, however, that *T. rubrocanus* does occur east through Nepal (Ali and Ripley 1987), and both *T. rubrocanus* and *T. albocinctus* breed in similar habitat in Bhutan (Inskipp *et al.* 2000). The absence of other species may be related to the absence of their preferred habitat. In particular, *Phylloscopus maculipennis* and *P. reguloides* are typically found in association with kharsu oak that is absent from Overa and further west.

High elevation Overa species missing from Manali: Eight of the 11 species present at high elevations in Overa but not present at high elevations in Manali are given in Table 3. Of the other three species, *Garrulax lineatus* and *Emberiza cia* are present and common in Manali, but only at low elevations (Appendix III). The third species missing from Manali, but not listed in Table 3, is *Phoenicurus caeruleocephalus*, which is very rare in Overa.

Table 3: Species common in Overa but absent or rare in Manali

Common name	Latin name	[1]Abundance	
		Overa	Manali
Common swift	*Apus apus*	20	0
[2,4]Chestnut thrush	*Turdus rubrocanus*	83	7
*Kashmir flycatcher	*Ficedula subrubra*	0	0
[4]Himalayan rubythroat	*Luscinia pectoralis*	37	0
*[4]Kashmir nuthatch	*Sitta cashmirensis*	0	0
[4]Simla crested tit	*Parus rufonuchalis*	30	0
Tytler's leaf-warbler	*Phylloscopus tytleri*	74	0
[4,5]White-browed rosefinch	*Carpodacus thura*	9	0
Orange bullfinch	*Pyrrhula aurantiaca*	47	0
[3,4]Tickell's warbler	*Phylloscopus affinis*	69	1

[1]Abundance at the high altitude sites (*c*. 3,200 m). See Table 1 for explanation.
*Common below 3,000 m in Overa (Price and Jamdar 1990) but never observed in Manali.
[2] In Manali, a nest with 3 eggs found at 3,500 m on June 18, 1996; an individual seen at 3,240 m on May 15, 2002.
[3]In Manali, a pair breeding in a small patch of juniper in 1994, and a single singing male in early May, 1995. May be common elsewhere in the Sanctuary where there is much juniper.
[4]Recorded breeding as far east as Nepal (Grimmett *et al.* 1999b).
[5]Two individuals seen near Manali town on May 8, 2002.

Eight of the 11 high-elevation species absent from Manali actually have ranges extending into Nepal, and their absence from Manali is attributable to patchy distribution. Causes of absence of these species from Manali are generally unclear, but several species have ecologically similar replacements (as noted in the previous section). Two species that are common in Overa, *Phylloscopus affinis* and *Luscinia pectoralis*, occur in juniper habitat which was rare at our study site in Manali. Both species have ranges extending through Nepal, and the patchiness in their distribution reflects the same in habitat distribution.

The three species present in Overa, but missing from Manali, which do not extend east are *Apus apus* (we have an unconfirmed sight record of this species in Manali), *Phylloscopus tytleri* and *Pyrrhula aurantiaca*. All three species are common in Overa. As in the case of Manali species not present in Overa, species abundant in one sanctuary are often absent from the other.

Altitudinal ranges: In general, and within the limits of our ability to accurately estimate altitudinal ranges, species that occur in both locations occupy similar altitudinal distributions. In particular, relative placements of congeners are never altered. There are three examples of large differences in altitudinal distribution between populations of the same species. All of these involve species in Overa extending to higher altitudes than in Manali (*Phylloscopus occipitalis*, *Garrulax lineatus* and *Emberiza cia*). Manali has the generally warmer climate, so we expected species at low elevations in Overa to have higher altitudinal distributions in Manali, but we found no clear examples of this pattern. It is possible that, given the lower species diversity in Overa, the altitudinal range extensions there are a response to reduced competition.

Similarities between sites: We calculated similarity indices (Magurran 1988, p. 95) between high and low elevations at Manali and Overa (Table 4). We restricted this analysis to passerines, which provide a more homogeneous set. The similarity indices are designed to run from 0 to 1. If there were an equal number of species in each site, all at the same density, an index of 0.5 would

Table 4: Similarities between sites for passerine birds

	High Overa	Low Overa	High Manali	Low Manali
High Overa	-	0.36	0.63	0.28
Low Overa	0.51	-	0.25	0.59
High Manali	0.59	0.35	-	0.23
Low Manali	-	-	-	-
Total species	53	38	63	35

Data from Table 4 of Price and Jamdar (1990) and Tables 1-3 in this paper.

Above the diagonal: Jaccard's index = (number shared species/total number species)

Below the diagonal: Morisita-Horn index, which weights species by their density (see Magurran 1988)

Densities were the fraction of days observed. This data is not available for low Manali.

Low sites are centred at approximately 2,400 m, high sites at approximately 3,200 m.

Low sites have fewer species because only forest species were included.

imply that half the species are present in both sites. Similarities within elevations across sites are about 0.6. Similarities between elevations run from 0.23 to 0.51 (true similarities are lower because only genuinely forest species are included for the lower sites; species of more open land are excluded). A shift in approximately 1,000 m elevation clearly results in more species' turnover than the shift of 250 km between Manali and Overa.

DISCUSSION

In South America, bird diversity is correlated with topography, precipitation and an interaction between topography and latitude (Rahbek and Graves 2001). The most diverse locality is in the Andes on the equator, which has: i) very high rainfall, probably related to productivity, and ii) a great diversity of habitats from tropical rainforest to Alpine tundra. A similar association is apparent across the Indian subcontinent: 80% of all land and freshwater bird species can be found in the vicinity of the Himalaya, and within the Himalaya the wetter southeast has a greater diversity of bird species than the drier northwest. Stainton and Polunin (1984) note similar patterns among the flowering plants.

As one moves from the northwest to southeast along the Himalaya, roughly 10% of all species occurring at one location are absent at a location 250 km further on. As one moves from southeast to northwest, the figures are more or less comparable, except from Nepal onwards, where about 30% of all species present at one location are missing from a location 250 km further northwest. The result is a steep decline in species diversity as one moves from west Nepal to northern Pakistan (as noted by Meinertzhagen 1928). The decline is associated with a latitudinal change of about 5 degrees, decreased precipitation and cooler spring weather.

The causes of turnover of species along the Himalayan transect are far from understood, so we undertook a comparison of the birdlife of two small sanctuaries separated by 250 km. We found that some species in one place are apparently replaced one-for-one by similar congeners in the other. Thus *Phylloscopus occipitalis* has a greater altitudinal range in Kashmir than in Himachal and this is associated with the absence in Kashmir of the similar *Phylloscopus reguloides*, occurring at high elevations in Himachal (Manali). The absence of *P. reguloides* from Kashmir is attributable to the absence of kharsu oak. We made a special study of the turnover of only *Phylloscopus* warblers (Price 1991, Price and Jamdar 1991), but more detailed studies of other species may result in similar explanations. At present, many patterns are unexplained. Several well-defined ecological groups present in Manali are simply missing from Kashmir, with no obvious counterparts. This includes some of the commonest birds in Himachal Pradesh such as a whole suite of ground foraging insectivores, a fantail-flycatcher and a minla.

One finding is that rarity in one sanctuary is no indication of absence from the other. At the same time, some of the commonest species in one sanctuary are entirely missing from the other. A possible explanation is that conditions in the non-breeding season limit population sizes. If this is the case, then subtle shifts in breeding requirements may be sufficient to concentrate the species in one location. For example, *Phylloscopus tytleri* has a very small range in Kashmir and northern Pakistan (where it is abundant) but does not occur in Manali. Price (1999) suggested that the population size of *P. tytleri* was severely limited by its specialised wintering requirements (the species is migratory and overwinters at relatively high altitudes in the central Western Ghats).

Our studies at Manali have revealed the presence of several species previously unrecorded in Himachal Pradesh (see Table 2 and Appendix II). Most striking was the discovery of *Pnoepyga immaculata,* previously thought to be confined to Nepal (Martens and Eck 1991). This discovery highlights the fact that many species have patchy distributions. In our comparison between the two sanctuaries, we found several examples where absence from one or other sanctuary is a result of a patchy distribution rather than the true species' range limit lying between the sanctuaries. Six of the 10 species listed in Table 3 that are common in Overa but absent from Manali actually have large populations elsewhere to the east of Manali, in some cases extending through Nepal. Patchy distributions are more striking for species present in Overa and missing from Manali than the converse. This may reflect the much greater extent of the Himalaya to the east rather than the west.

Although range maps in Grimmett *et al.* (1999a) indicate several species with clearly patchy distributions on a regional scale, patchiness on a more local scale has scarcely been investigated, and needs more research. For example, we do not know how extensive the distribution of *Pnoepyga immaculata* is beyond Manali. As a second example, Gaston *et al.* (1993) never recorded *Luscinia brunnea* in their surveys of the Great Himalayan National Park, approximately 50 km to the south of Manali. However, this species is one of the commonest species at both Manali and Overa.

At any given locality, there is high species' turnover along the elevational gradient, and bird communities separated by 1,000 m altitude are more different than the communities in Manali and Overa at the same altitude. Hunter and Yonzon (1993) have recorded the presence of many species with restricted altitudinal ranges in Nepal and point to the need for preserves at all elevations. Despite this, there are large differences in species' composition at different localities along the Himalaya, and Arunachal shares less than one-quarter of its species with Pakistan. There is a tendency to treat the Himalaya as a unit with respect to conservation issues, because the threat of habitat destruction is universal throughout the range. This analysis demonstrates that the Himalaya is actually quite diverse, and each area has its own needs. Each area must have its own nature preserves if Himalayan biodiversity is to be conserved.

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APPENDIX I: Additions/corrections to the Overa Sanctuary list (in Price and Jamdar 1990, 1991)

1. Price and Jamdar (1990, 1991) reported on the birds of Overa Sanctuary based on 3 years' fieldwork (1985-1987). Our subsequent work at Overa for 1-2 months in each of the years 1988, 1989, 1990 and 1991, confirmed the altitudinal distributions previously reported and confirmed breeding for some species.
2. One additional species was recorded: large pied wagtail *Motacilla maderaspatensis* near Overa village.
3. In Price and Jamdar (1990), we stated that two species, *Mycerobas icterioides* and *Carpodacus rhodochrous* bred throughout the entire altitudinal range that we studied (2,430-3,725 m). Although we recorded both species throughout the range, we are not sure that they breed in all locations. In particular, it remains to be determined that both the species breed at the highest and lowest altitude sites, and it appears unlikely that *M. icterioides* breeds at the highest altitude.
4. In Price and Jamdar (1991), we noted that *Phylloscopus reguloides* is absent from Overa and were unsure where *P. reguloides* and *Phylloscopus occipitalis* breed in sympatry. We now know they occur sympatrically from the Kashmir border in the Chamba region of Himachal Pradesh to at least the Nepal border in Kumaon (including Manali). *P. reguloides* breeds at generally higher altitudes (e.g. Table 1 of this paper).
5. In Price and Jamdar (1990), the generally uncommon spruce was not separated from fir in Table 1. In Table 4, printer's errors resulted in omission of some data and mismatching of columns. The altitudinal distributions and densities at high elevation of all species are given in Table 1 of this paper, and the mismatched columns in Price and Jamdar (1990) can be worked out.

APPENDIX II: Rare or unusual birds recorded in Manali Sanctuary

Tibetan snowcock *Tetraogallus tibetanus*: A flock of 10 at 3,825 m on June 1, 2001. We do not know if this species is common, as we rarely visited higher altitudes.

Snow pigeon *Columba leuconota*: Eight birds seen on May 9, 2001, also seen rarely in Overa.

Black-naped green woodpecker *Picus canus*. Observed on May 24, 2002 at 2,430 m elevation.

Speckled wood-pigeon *Columba hodgsonii*. One bird seen on May 19, 2001 and two on May 8, 2002 in lower elevation forest, also seen once at Overa.

Grey treepie *Dendrocitta formosae*. One bird seen on May 19, 2001 at 3,100 m. Also seen in Manali town in May, 2002.

Long-tailed thrush *Zoothera dixoni*. A nest with 3 nestlings discovered at *c.* 3,100 m on May 23, 2002. Possibly more common in Manali and was previously overlooked by us.

Gould's shortwing *Brachypteryx stellata*. A male singing on June 6, 1994, in a juniper bush at *c.* 3,500 m. There are only a few earlier observations of this very distinctive species west of central Nepal, and none west of Uttaranchal. Despite searching, the species was not observed again.

Chaffinch *Fringilla coelebs*. A male singing on top of a cedar on May 4, 1994, at 2,000 m elevation. A rare winter visitor to the Himalaya (Grimmett *et al.* 1999b).

Little forktail, *Enicurus scouleri*. Observed twice in the sanctuary, once at *c.* 3,200 m. It is probable that the species breeds regularly but not confirmed, for watercourses were not regularly checked.

Yellow-browed tit, *Sylviparus modestus*. A pair feeding 4 young in a moss cup in hole in tree, June 11, 1997 at 2,750 m.

Grey-cheeked flycatcher-warbler, *Seicercus poliogenys*. A male singing at 2,500 m in a chestnut grove, first seen May 17, 2001, still present June 26, 2001, and still singing loudly and presumably unmated. Apart from possible records by Green (1986) in atypical habitat, this species has not been recorded west of Central Nepal (Grimmett *et al.* 1999b).

Fire-tailed sunbird, *Aethopyga ignicauda*. A male was captured and present in the study area on rhododendron (*c.* 3,300 m.) throughout June, 1997. It may have bred.

Two species are in Table 3 (*Turdus rubrocanus* and *Phylloscopus affinis)* and are not repeated here.

Appendix III: Additional species of Manali

Many of the following species are found in Manali town and on agricultural land, but have been recorded along the lower boundary of the Sanctuary (I = Infrequently observed). Note that this list includes only those species not in Tables 1 or 2.

Brown-fronted pied woodpecker *Dendrocopos auriceps* (I)
Small blue kingfisher *Alcedo atthis*
Oriental cuckoo *Cuculus saturatus*
Indian cuckoo *Cuculus micropterus* (I)
Blue rock pigeon *Columbia livia*
Common sandpiper *Actitis hypoleucos*
Eurasian hobby *Falco subbuteo*
Common hoopoe *Upupa epops*
Rufous-backed shrike *Lanius schach*
Yellow-billed blue magpie *Urocissa flavirostris*
Eurasian golden oriole *Oriolus oriolus* (I)
Asian paradise-flycatcher *Terpsiphone paradisi* (I)
Brown dipper *Cinclus pallasii*
Tickell's thrush *Turdus unicolor*
Oriental magpie-robin *Copsychus saularis*
Plumbeous redstart *Rhyacornis fuliginosus*
Spotted forktail *Enicurus maculatus*
Grey bushchat *Saxicola ferrea*
Common stonechat *Saxicola torquata* (I)
Common myna *Acridotheres tristis*
Jungle myna *Acridotheres fuscus*
Great tit *Parus major*
Red-headed tit *Aegithalos concinnus*
Himalayan bulbul *Pycnonotus leucogenys*
Oriental white-eye *Zosterops palpebrosus*
Brown-flanked bush-warbler *Cettia fortipes*
Streaked laughingthrush *Garrulax lineatus*
Rufous sibia *Heterophasia capistrata* (I)
House sparrow *Passer domesticus*
Cinnamon tree sparrow *Passer rutilans*
White wagtail *Motacilla alba*
Large Pied wagtail *Motacilla maderaspatensis*
Grey wagtail *Motacilla cinerea*
Spotted munia *Lonchura punctulata* (I)
Yellow-breasted greenfinch *Carduelis spinoides*
Eurasian goldfinch *Carduelis carduelis*
Common rosefinch *Carpodacus erythrinus*
Grey-headed bunting *Emberiza fucata*
Rock bunting *Emberiza cia.*

Note: *Cettia fortipes* has been recorded up to 2,225 m and *Rhyacornis fuliginosus* at 2,700 m. Both these species are of interest, in that they appear to occur at much higher elevations in Overa than in Manali. *Emberiza cia* has been recorded up to 3,200 m in Overa, but only 2,000 m in Manali. *Garrulax lineatus* has been recorded

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FRUGIVORY, SEED DISPERSAL AND REGENERATION BY BIRDS IN SOUTH INDIAN FORESTS

(With seven text-figures and one plate)

P. Balasubramanian[1,2] and B. Maheswaran[1]

Key words: Tropical forest, bird-fruits, avian frugivores, seed dispersal, fruit size, forest regeneration, Western Ghats

Plants, unlike animals, are immobile and have little control over the choice of site where they can live and grow. Over aeons, plants have perfected the art of survival in spite of this disability by steadily interacting with the animals in their habitat. The evolution of brilliant, attractive colours and endowment of the fruits with nutritious supplements such as proteins, lipids and carbohydrates, have appealed to the dietary needs of birds and mammals. Furthermore, the plant's ability to asynchronously produce fruits, for the assemblage of vertebrates dependent on fruits have made their dispersal possible. Plant-bird interactions play a pivotal role in maintaining the structural and functional integrity of natural ecosystems. Also, the interactions guide the process of evolution of biodiversity as well as ecological communities. On account of their unparalleled richness, tropical communities are treasure troves of biological interactions between plants and animals. Ecological degradations, as in shrinking habitats and fragmentation, necessitate a comprehensive understanding of the basic tenets of interacting entities, in order to evolve effective strategies to preserve and enrich our biodiversity.

INTRODUCTION

Birds play a prominent role in pollination and seed dispersal of plants. The flower visiting birds, while harvesting nectar, pollinate their food plants. Similarly, the fruit eating birds by devouring the pulpy fruits distribute the seeds of their food plant species. Birds, by virtue of their habits, can play a more effective role in seed dissemination than other animals. Compared to other vertebrates, which disseminate the seeds in clumps, the seed deposition pattern of birds is more efficient. The interactions between flower-birds and bird-flowers have been discussed (Ali 1931, Subramanya and Radhamani 1993). A variety of birds and mammals depend predominantly on fruit to fulfil their nutritional requirements. Such fruit-eating birds and mammals are termed as frugivores. Fruit traits such as colour, size and nutritional supplements have evolved in response to interacting vertebrates. The evolution of fruit syndromes, complemented by the birds' adaptive ability to recognise these syndromes, along with physiological and anatomical modifications to process the fruit diet have been the key in the contemporaneous plant-bird interactive relations. Such persistent relationships have given rise to mutual dependence, benefiting both elements.

Though fruit-frugivore interactions have been studied by various authors during recent times, there is no consolidated information on the role of birds in seed dispersal and forest regeneration. Information is available on the fruit types consumed by various bird species in India, but only a few studies attempted to quantify the role of birds in forest regeneration. A review of those studies and reference to the various floras indicate that several families benefit from birds for their regeneration. Known syndromes of bird-dispersed fruits help to identify various bird-fruits from hitherto unexplored bird habitats.

Frugivores help seeds escape from the deleterious effects of seed and seedling predators (Janzen 1970). Differences in frugivore activity have profound effects on the conditions under which seeds and seedlings must survive, and consequently should influence the evolution of tree demographies. The relationship between seed dispersal and seedling demography has profound implications for tropical conservation policy

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(Howe 1984). Seasonality in fruit production in tropical forest ecosystems has brought to light the roles played by 'keystone' or 'pivotal' species during periods of scarcity.

Studies on fruit-frugivore interactions conducted by us as part of research programmes under the Bombay Natural History Society (BNHS) and the Sálim Ali Centre for Ornithology and Natural History (SACON) for the past two decades helped us to arrive at certain conclusions and also comprehensively list the plant genera dispersed by birds in south India. The material for this paper has been derived mainly from the Tropical Dry Evergreen Forests of Point Calimere, and the Semi-evergreen, Dry and Mixed Deciduous Forests of the Western Ghats. Though seed dispersal is effected by exozoochorous methods (dispersal effected by seeds clinging on to body parts of birds and animals) also, we would like to state that the review exclusively deals with endozoochory (dispersal wherein fruits are ingested, the pulp digested and the seeds defecated or regurgitated).

OBSERVATIONS

Frugivory and seed dispersal in south India

The present review is based on three major research efforts in south India – on the Tropical Dry Evergreen Forests in Point Calimere, Dry Mixed Deciduous Forests of Coimbatore Division and Semi-evergreen forests of Mudumalai Wildlife Sanctuary (MWLS), Western Ghats. The lists of fruit-eating birds and bird-dispersed fruit species have been compiled chiefly from these three major studies and have been summarised in Appendix I and II.

A total of 66 species (36 genera) of Indian birds from 16 families have been documented for frugivory in south India. Bird species of families Columbidae (pigeons), Pycnonotidae (bulbuls) and Muscicapidae (flycatchers) contributed the maximum number of frugivorous species (7 species). While Sturnidae (mynas) hold 6 frugivorous species, Psittacidae (parrots) and Capitonidae (barbets; Plate 1, Fig. 1) hold 5 species each. Among the 66 species of fruit-eating birds, members of Columbidae (except the mountain imperial-pigeon) and Psittacidae (parrots) digest the seeds and hence are considered as seed predators. Other frugivores could be considered as legitimate seed dispersers.

The body size varied considerably among frugivorous birds (range 5-2,500 g; Appendix I; Fig. 1). Hornbills (Family Bucerotidae) were the heaviest birds, having a mean body weight of 1,246 g (n=3) followed by Family Corvidae (crows) and Columbidae (pigeons) whose mean body weight was 288 g (n=4) and 246 g (n=7) respectively. The great pied hornbill *Buceros bicornis*, a charismatic flagship species of the Western Ghats and northeastern India, is the heaviest among frugivores, weighing 2,500 g followed by Malabar pied hornbill *Anthracoceros coronatus* (1,000 g), jungle crow *Corvus macrorhynchos* (650 g) and the mountain imperial -pigeon *Ducula badia* (580 g). Hornbills and pigeons are also voracious frugivorous bird species in their habitat.

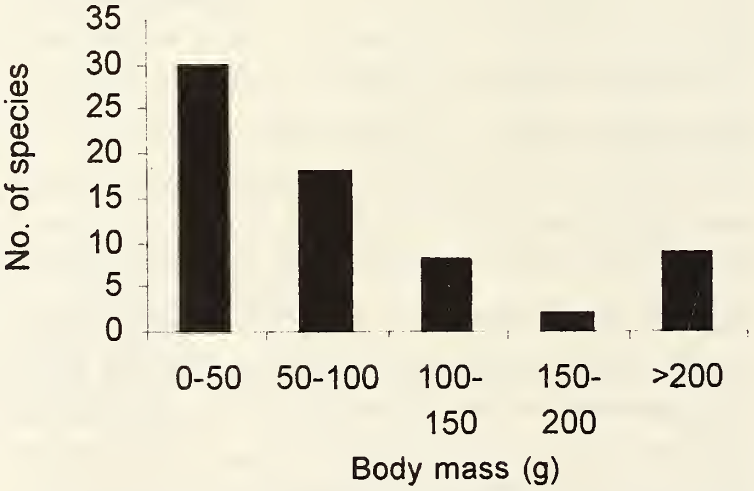
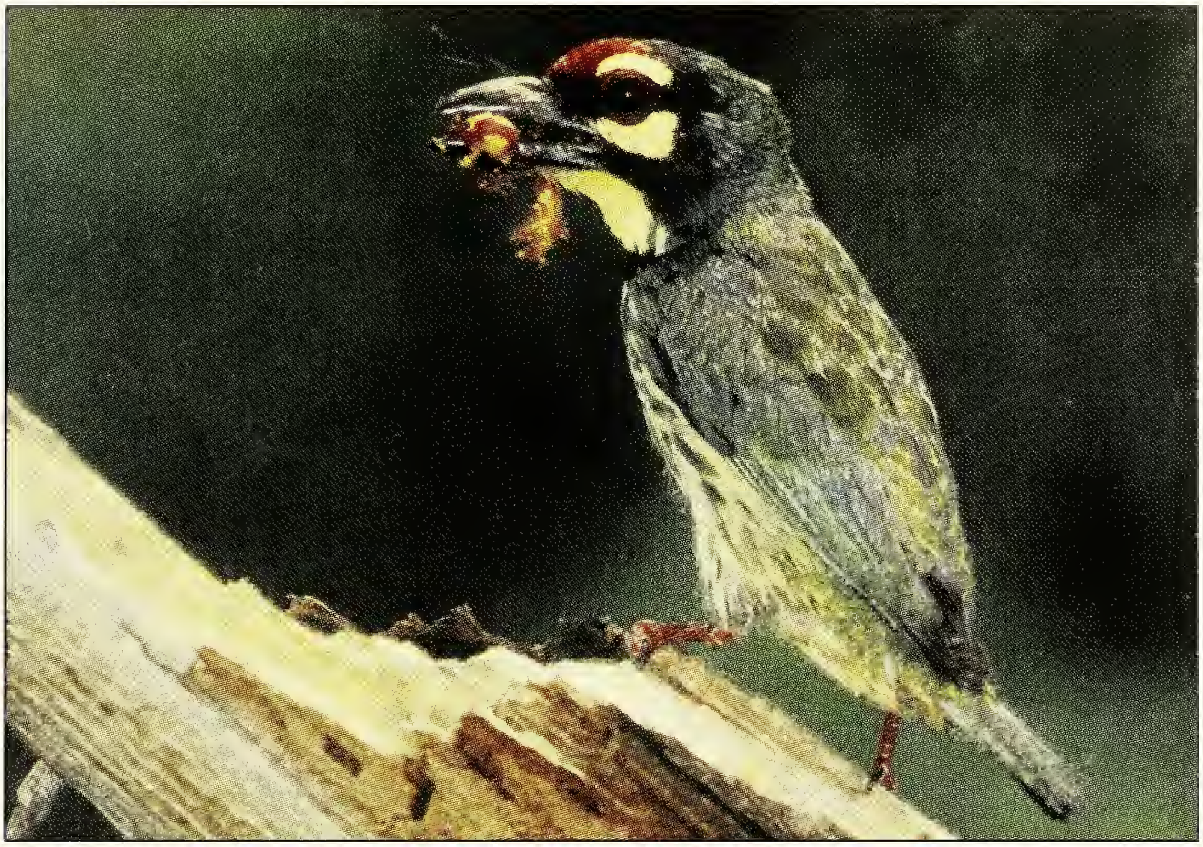


Fig 1: Body mass of frugivorous birds in south Indian forests (n=66)

Bird attracting flora in south India

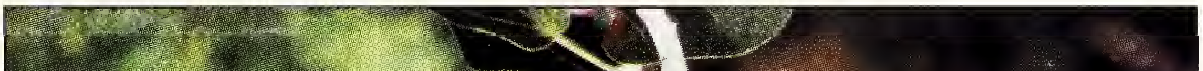
Fruits of 219 species (141 genera) belonging to 61 plant families were recorded to be used by frugivorous birds. The members of the families Lauraceae (21 species), Euphorbiaceae

Balasubramanian, P. *et al.*: Species involved in frugivory in Western Ghats PLATE 1



K. MARUDHACHALAM

Fig. 1: Coppersmith barbet *Megalaima haemacephala*, a frugivore and major seed disperser of forest trees, at Coimbatore Forest Division



P. BALASUBRAMANIAN

Fig. 2: *Ficus benghalensis*, a keystone species for avian frugivores, in the Coimbatore Forest Division

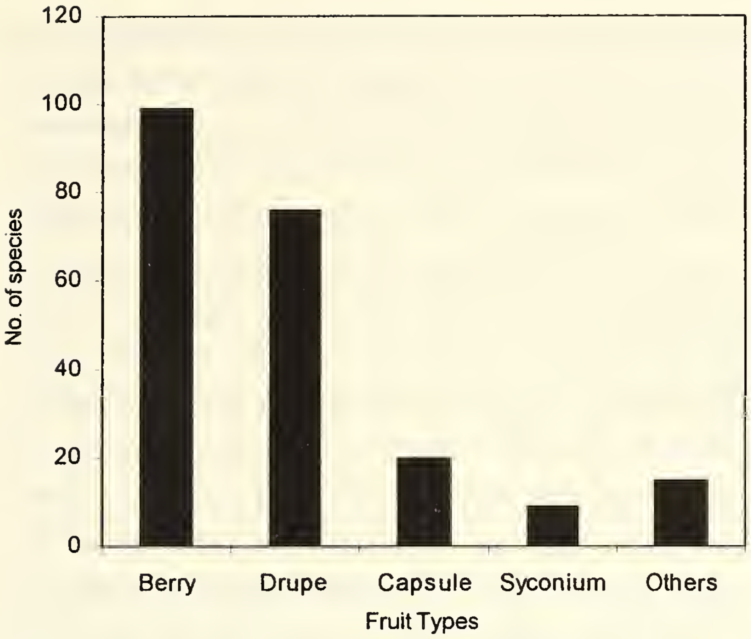


Fig. 2: Morphological classification of bird-dispersed fruits in south Indian forests (n= 219)

(13 species), Rubiaceae (12 species), Moraceae (10 species), Meliaceae and Annonaceae (9 species each) were most represented among fleshy-fruited species adapted for frugivory. The genus *Ficus* (figs), known for their ability to produce fruits asynchronously and support the frugivore community during periods of scarcity, was represented by 8 species. The genera *Eugenia* and *Litsea* were represented by 5 species each, while *Capparis*, *Cinnamomum*, *Diospyros* and *Zizyphus* were represented by 4 species each (Appendix II).

The fruit types of all the 219 species were determined. Berries were the predominant fruit type borne by 99 species (45%) while drupes were borne on 76 species (35%) and together accounted for 80% of the fruits for the whole of south India (Fig. 2). Fleshy-fruited plants are very common in tropical forests, with frequencies usually over 70% (of woody plants) in the forests and lesser in the dry forests. The frequency of fleshy-fruited plants in the Dry Deciduous Forests of Coimbatore was 65%, while in Tropical Dry Evergreen Forests of Point Calimere it was 73%. In the Semi-evergreen Forest of Mudumalai Wildlife Sanctuary, Western Ghats, 57% of the species and 74% of individuals were fleshy-fruited species.

Colours of ripe fruits for all the 219 species were assigned to one of eight broad colour categories as used by Wheelwright and Janson (1985). The analysis showed that 94 species (43%) produced black fruit while 58 species (26%) produced red fruit and 39 species (18%) produced yellow fruit (Fig. 3). Black and red accounted for 70% of species.

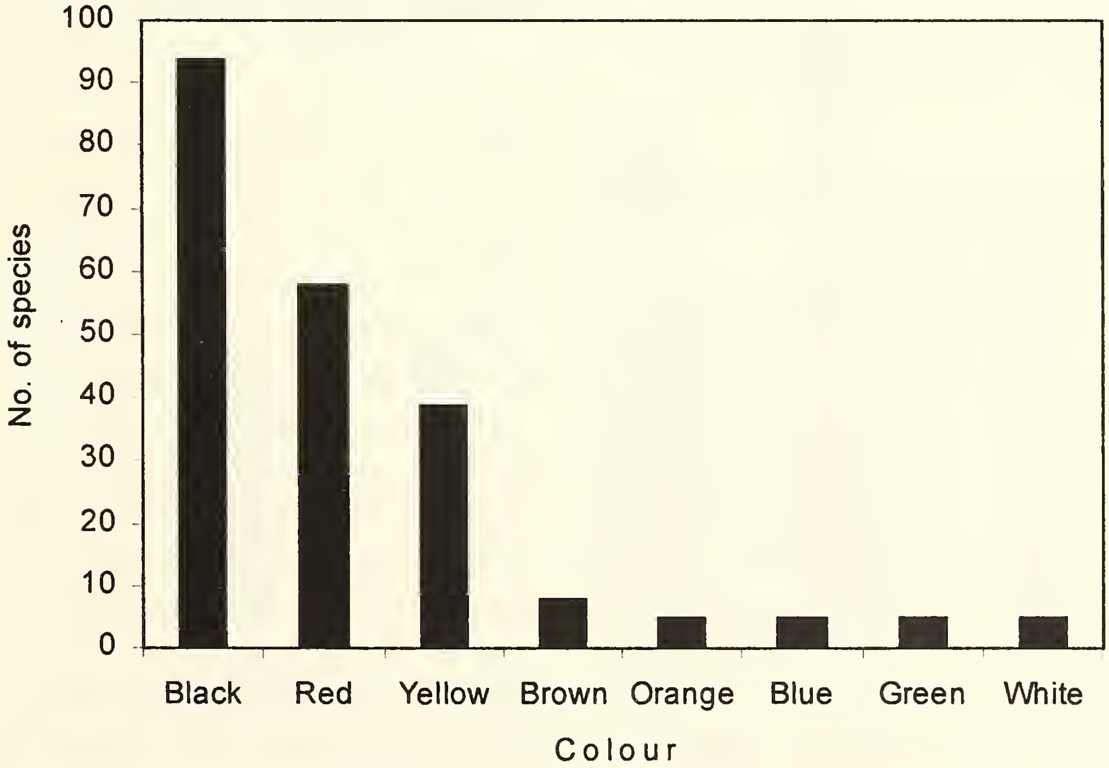


Fig. 3: Colours of bird-dispersed fruits in south Indian forests (n=219)

Analyses of the fruit diameter revealed that 98 species (45%) had their fruit sizes 10-20 mm, while another 85 species (39%) bore fruits in the size range <10 mm. Only 36 of the 219 species (16%) bore fruits of size greater than 20 mm (Fig. 4). About 83% of fruits were less than 20 mm in diameter. Plants of Families Annonaceae, Burseraceae, Elaeocarpaceae, Meliaceae, Moraceae and Myristicaceae produced large fruits while plants of Families Cucurbitaceae, Cordiaceae, Ebenaceae, Lauraceae, Melastomataceae, Menispermaceae, Oleaceae and Rubiaceae produced small fruits.

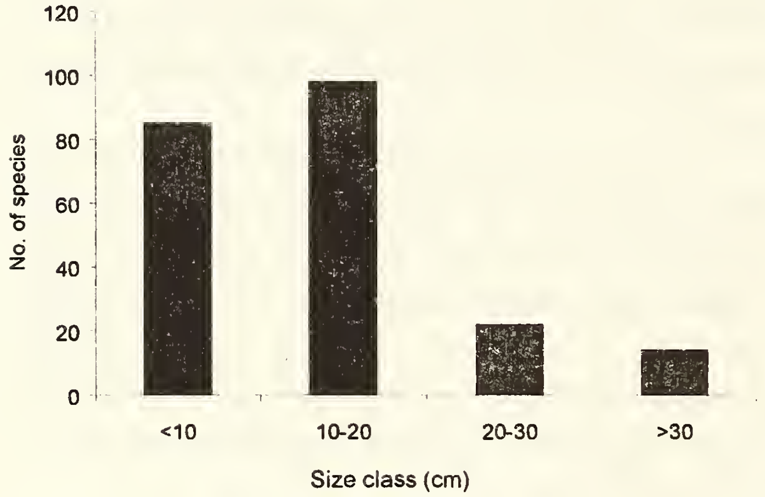


Fig. 4: Fruit size classification of bird-dispersed fruits in south Indian forests (n=219)

Birds and regeneration in Tropical Dry Evergreen Forest, south India

A study on the interrelationships between fleshy-fruited plants and their vertebrate consumers was conducted in the Dry Evergreen Forest in Point Calimere, south India in the mid-1980s (Balasubramanian 1996). During the course of the study, 317 species of flowering plants were recorded, of which 88 bore fleshy fruits. Sixty-four of the 88 fleshy-fruited species were adapted for frugivory by birds. A total of 20 bird species of 14 genera from 10 families were observed to eat fruits at Point Calimere. The major avian seed dispersers documented were the white-browed bulbul *Pycnonotus luteolus*, red-vented bulbul *Pycnonotus cafer*, jungle myna *Acridotheres fuscus*, brahminy starling *Sturnus pagodarum*, jungle crow *Corvus macrorhynchos*, house crow *Corvus splendens* and Asian koel *Eudynamys scolopacea*. Other seed dispersers included rosy starling *Sturnus roseus*, Eurasian golden oriole *Oriolus oriolus*, Indian tree pie *Dendrocitta vagabunda*, jungle babbler *Turdoides striatus* and Tickell's flowerpecker *Dicaeum erythrorhynchos*. *Pycnonotus luteolus* visited maximum number of plants (63), followed by *Pycnonotus cafer* (51), *Eudynamys scolopacea* (32) and *Acridotheres tristis* (27). Three plant species were visited by more than 10 bird species. *Salvadora persica* was visited by maximum number of bird species (15), followed by *Manilkara hexandra* (12) and *Ficus infectoria* (11).

Even though nearly 50% of the fleshy-fruited species in Point Calimere were consumed by mammals, only 10% of the species were solely dispersed by mammals. Most plant species are chiefly dispersed by birds.

Birds and natural regeneration in Dry Mixed Deciduous Forest, Western Ghats

In an effort to understand the tenets of restoration ecology with birds as the basis of regeneration, a project was launched by SACON in cooperation with the Tamil Nadu Forest Department. The studies were conducted in the Dry Mixed Deciduous Forest, Coimbatore Forest Division, Western Ghats (Balasubramanian *et al.* 1998). Of the 115 woody species recorded in the study area, 52% of the species were bird-dispersed. Figs attracted maximum number of bird species followed by *Celtis philippensis* and *Syzygium cumini*. Of the 35 fruit-eating bird species, 18 (51.42%) were major frugivores. The red-vented, white-browed and red-whiskered bulbuls were most frequent visitors to fruit trees in the Dry Deciduous Forest. In the riverine forest, barbets, bulbuls, mynas, the Asian fairy bluebird and koel were major frugivores. The Malabar pied hornbill, one of the largest frugivores of the Indian subcontinent, were seen to feed on fruits of *Ficus* sp., *Strychnos nux-vomica* and several other large-fruited species in the riverine forest (Balasubramanian and Saravanan 2001).

Five species, namely *Ficus benghalensis*, *F. racemosa*, *Celtis philippensis*, *Cassine glauca* and *Strychnos potatorum*, were experimented with to determine if the birds enhanced germination capacity of seeds that passed through their intestinal tracts. The germination percentage of seeds dispersed by birds was significantly higher than that of the seeds collected from plants for four species. In one species *Celtis philippensis*, although a similar trend was observed, the difference was not significant (Fig. 5).

Natural regeneration of bird-dispersed plants was studied in the Dry Mixed Deciduous Forests of Coimbatore Division in Tamil Nadu. The density of seedlings and saplings of bird-dispersed trees varied from 279 per hectare in the highly degraded habitat to 640 in the undisturbed habitat. Twelve out of the 15 species had good regeneration potential, represented by more than 10 saplings. In the highly degraded habitat, only 3 out of 9 species had more than 10 saplings.

Hornbills and forest regeneration in Semi-evergreen and Evergreen Forests

Malabar grey hornbill (*Ocyceros griseus*), an endemic frugivore of restricted range in the moist forests of Western Ghats, south India, is dependent on fruit resources and suitable nest trees for subsistence. As a consequence of its specialised breeding habits and dependence on fruits as a predominant source of food, this hornbill is known to interact with a variety of tree species. The Malabar grey is considered one of the keystone species and a major seed disperser in the Western Ghats region (Mudappa 2000).

Like most other hornbills, the Malabar grey is known to bring a large load of fruit to the nesting site to feed the incarcerated female and chicks during the breeding season. Seeds of fruits consumed are squirted out through the nest slit, and get embedded in the litter-strewn forest floor. These seed deposits are usually termed as midden.

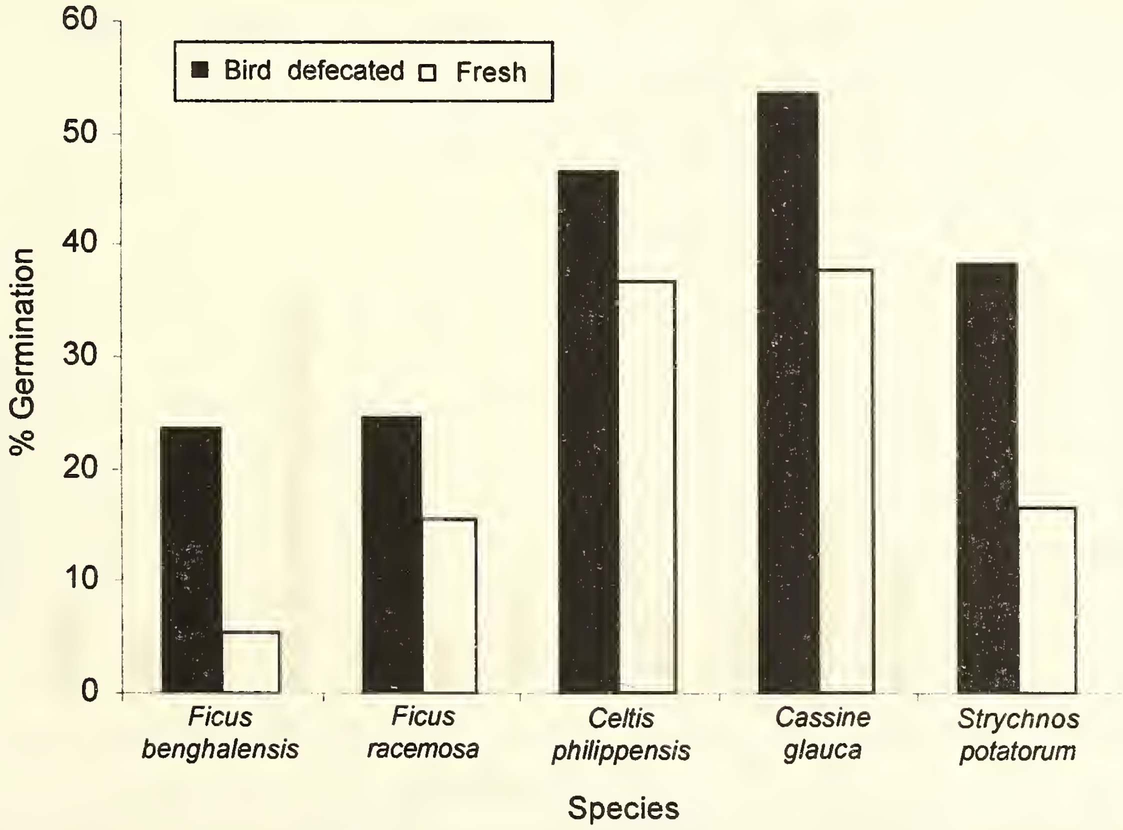


Fig. 5: Percentage germination of bird-defecated and fresh seeds, Coimbatore Forest Division

Monitoring the midden deposits and analysing the seeds therein during breeding season, helped to determine the variety of fruit species consumed and dispersed by this hornbill. The study was conducted in the Semi-evergreen Forests of Mudumalai Wildlife Sanctuary (Balasubramanian and Maheswaran 2001). Tree species common to this vegetation type are *Olea dioica, Actinodaphne malabarica*, *Persea macrantha*, *Cinnamomum verum*, *Lagerstroemia microcarpa*, and *Terminalia* sp.

Of the 1,430 individuals belonging to the 70 tree species present, 74% of individuals and 56% of the species were adapted for frugivory. Major disperser species in this habitat, apart from the Malabar grey hornbill (*Ocyceros griseus*), were the fruit pigeons (*Ducula badia*), barbets (*Megalaima* sp.), mynas (*Acridotheres* sp.) and starlings (*Sturnus* sp.). During the breeding season, an intensive nest search was conducted in the semi-evergreen patches of Mudumalai Wildlife Sanctuary for nesting activity of the Malabar grey hornbill. Cavities of trees used by hornbills for nesting were located by following breeding pairs of hornbills, prior to the breeding season. Twelve nests in the breeding season were selected for studying midden regeneration. Two square plots (5 sq. m each) were demarcated for each nest site, one behind and one in front of the nest. During the post-breeding season (May-January), these sites were visited every week to study regeneration from the midden deposits.

New seedlings of a total of 19 species belonging to 13 families were enumerated from the square plots. *Olea dioica*, one of the favoured fruits of this birds was recorded in all the 12 midden sites, while *Cinnamomum verum* was recorded from 11 midden sites. Lauraceae and Flacourtiaceae (3 species each) were the most represented families among the regenerated seedlings. The number of seedlings regenerated in front of the nest was significantly higher than those behind the nest ($X^2 = 298.378$; df = 9; $P < 0.005$). While 13 species comprising 280 regenerated seedlings were recorded behind the nests, 18 species comprising 761 seedlings had regenerated in front of the nest site, just below the nest hole, i.e. 63% more seedlings regenerated in front of the nest. Greater regeneration in front of the nest was seen at all the sites except nest site 9 (Fig. 6). Regeneration within a species was also found to be significantly higher in front of the nest ($X^2 = 213.823$; df = 8; $P < 0.005$).

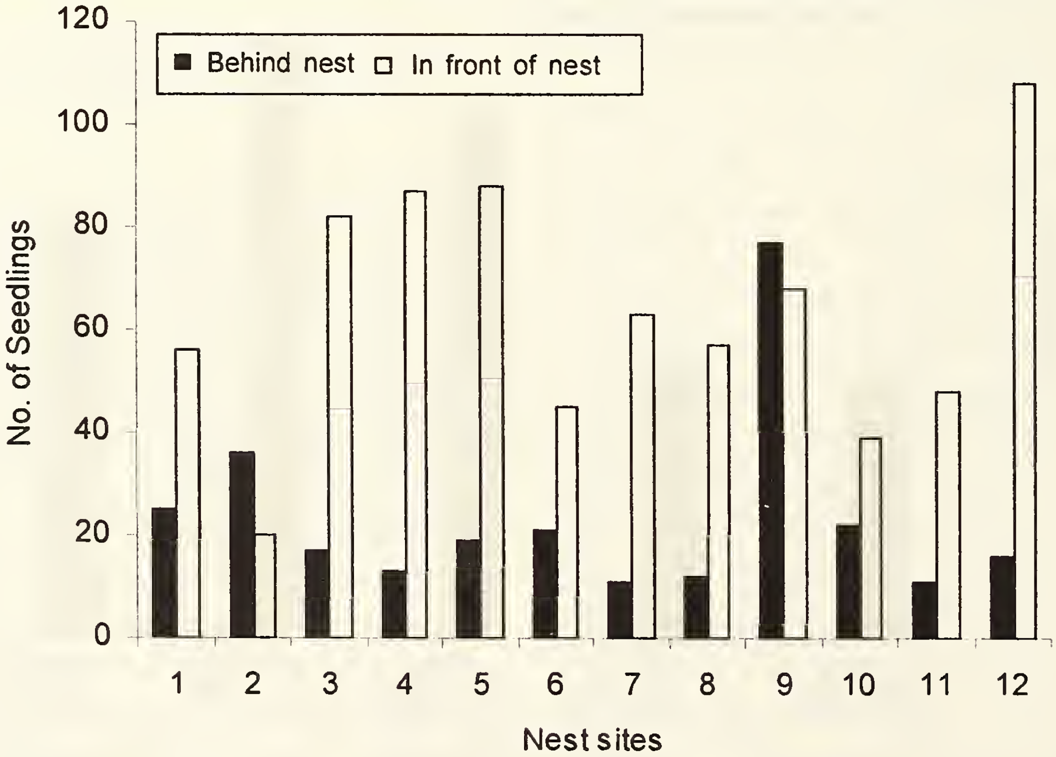


Fig. 6: Regeneration of seeds behind and in front of Malabar grey hornbill nests in a Semi-evergreen Forest at Mudumalai Wildlife Sanctuary, Western Ghats

Germination experiments were conducted at the study site using seeds collected from the midden, and control seeds of ripe fruits collected directly from trees for comparison. Seeds of two preferred fruit species, *Olea dioica* and *Persea macrantha*, were chosen for seed germination studies. The soil conditions in which the experimental seeds were planted were the same as they would be in the midden. Seeds were sown in polythene bags under open conditions and watered regularly.

After four months of continuous monitoring of the seedlings, it was observed that bird-defecated seeds had a higher regeneration potential than control seeds collected directly from plants. Bird-defecated seeds of *Olea dioica* showed 41.67% higher germination rate than fresh seeds while for *Persea macrantha*, the bird-defecated seeds showed 75% enhanced germination over the control seeds (Fig. 7). A statistical comparison of the bird-defecated and control seeds for both the species showed a significantly higher rate of germination for bird-defecated seeds ($X^2 = 90.739$; df =1; $P<0.005$).

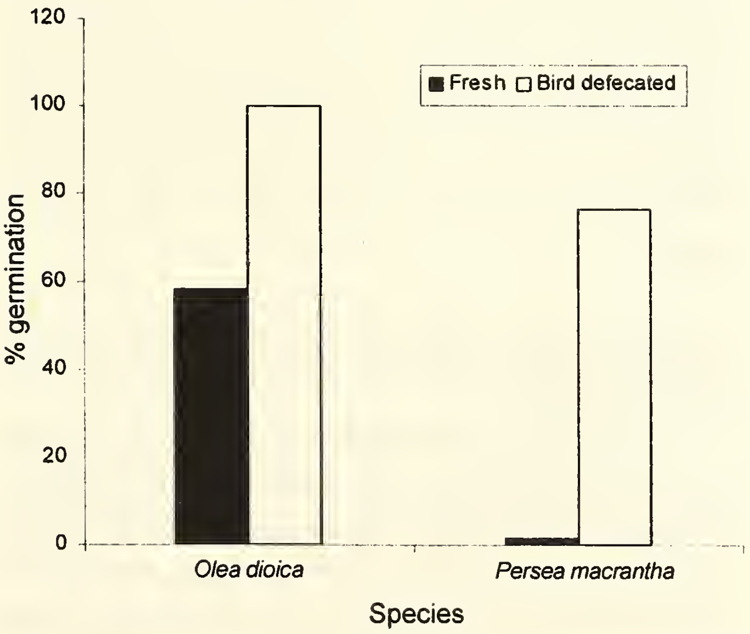


Fig. 7: Percentage germination of seeds defecated by Malabar grey hornbill and control seeds, in two plant species at Mudumalai Wildlife Sanctuary, Western Ghats

Bird-aided regeneration in other forests of the Western Ghats and coastal plains

Hornbills are one of the dominant frugivores and seed dispersers of the palaeotropical region. In the Asian tropical forests, they have been well studied for frugivory, especially in the breeding season, and are known to disperse the seeds undamaged (Leighton 1981). Hornbills, for most part of the year, are scatter dispersers, but during the nesting season large numbers of seeds are deposited under the nests, creating conspicuous middens. Our study in the Semi-evergreen Forests of Mudumalai Wildlife Sanctuary, Western Ghats has established that the Malabar grey hornbill utilises 27 different fleshy-fruit species, and 16 species were recorded to have regenerated from the midden under nest trees of hornbills. Kannan and James (1999) identified 21 species of trees with lipid-rich fruits, utilised by hornbills (*Buceros bicornis* and *Ocyceros griseus*). These included 12 *Cinnamomum*, 2 *Myristica*, 2 *Beilschmedia*, 2 *Dysoxylum*, 1 *Persea* and 2 *Polyalthia* species.

In a study in the Moist Deciduous Forest habitat in the Western Ghats of Kerala (Vijayakumar and Zacharias, in press) showed that the major frugivores were the white-cheeked barbet *Megalaima viridis*, crimson-throated barbet *Megalaima rubricapilla*, pompadour green-pigeon *Treron pompadora*, black bulbul *Hypsipetes leucocephalus* and common hill-myna *Gracula religiosa*.

In the Wet Evergreen Forest of Kalakad-Mundanthurai Tiger Reserve, southern India, birds dispersed 59% of the 65 fleshy-fruited tree species (Ganesh and Davidar 2001). About 33% (16) of bird-dispersed species belonged to Family Lauraceae. While small birds dispersed 86% of the plant species, pigeons dispersed 14% of large fruited species. The six common frugivorous species of that habitat were black bulbul *Hypsipetes leucocephalus*, yellow-browed bulbul *Iole indica*, red-whiskered bulbul *Pycnonotus jocosus*, white-cheeked barbet *Megalaima viridis*, mountain imperial-pigeon *Ducula badia* and Nilgiri wood-pigeon *Columba elphinstonii.*

Effects of hornbills on seeds have been documented for 34 species in Dja Reserve, Cameroon (Whitney *et al.* 1998). Seeds of most species were egested without much physical damage. Germination trials on 24 species showed that 23 species germinated after egestion by two hornbills, *Ceratogymna atrata* and *C. cylindricus*, and a major proportion of these species did not exhibit a fall from the germination rate in control seeds.

A study on plant-bird interaction in the Tropical Evergreen Forest of the erstwhile Chengalpattu district, Coromandel coast, southern India, showed that 130 out of the 180 woody plants (72%) bore fleshy fruits (Narasimhan *et al.* 1993). Major fleshy-fruited species included *Zizyphus oenoplia, Allophyllus serratus, Ficus benghalensis, Benkara malabarica, Hugonia mystax, Tarenna asiatica, Memecylon umbellatum, Carmona retusa* and *Dendrophthoe falcata.* Though 150 birds have been recorded from this region (Siromoney 1971), only 20 are involved in seed dispersal. Families of frugivorous birds recorded include Columbidae, Cuculidae, Capitonidae, Oriolidae, Sturnidae, Corvidae, Irenidae, Pycnonotidae and Muscicapidae. In this forest, berries and drupes were the major fruit types encountered, while red (48%) followed by black (31%) were the predominant fruit colours. The study also showed that 72% of the fruits were less than 1 cm in diameter, indicating the role of generalist frugivores in dispersal.

Bulbuls have established themselves as one of the dominant frugivores and seed dispersers in scrub jungles or forests of secondary vegetation in Asia, Africa and the Middle East (Lever 1987). In the Tropical Dry Evergreen, as well as Dry Mixed Deciduous Forests of south India, bulbuls are the predominant frugivorous and seed dispersing species (Vijayan 1975, Balasubramanian 1996, Balasubramanian *et al.* 1998). In Point Calimere (Balasubramanian 1996), 74% of the visits by birds on fruiting plants were by two species of bulbuls. In the Dry Deciduous Forests of Coimbatore (Balasubramanian *et al.* 1998), the largest number of visits (47.5%) were by 3 species of bulbuls followed by 3 species of barbets (18.46%). In a study in the subtropical shrub lands of Hong Kong, two species of bulbuls, the red-whiskered bulbul (*Pycnonotus jocosus*) and the light-vented bulbul (*Pycnonotus sinensis*), were the most important seed dispersal agents. These species have an unusually large gape width for their size, and they utilise this advantage to the maximum (Corlett 1998). The dominant role of bulbuls in frugivory and dispersal in tropical forest communities makes them a valuable group of birds.

Research on plant-bird interactions at Point Calimere showed that conspicuous colour combined with small size of fruit enabled frugivorous birds to access fruit resources easily (Balasubramanian 1996). According to Terborgh and Diamond (1970), small-fruited plant species attract more species of birds than large-fruited ones. Corlett (1996) observed that most of the bird-dispersed seeds in Hong Kong had a mean diameter of <13 mm. This trend was consistent with findings from the Neotropics (Janson 1983, Howe 1986), Africa (Knight and Siegfried 1983, Gautier-Hion *et al.* 1985), Australasia (Beehler 1983, Green 1993) and in Indonesia (Suryadi *et al.* 1994).

Birds and enhancement of seed germination and regeneration

Frugivores affect the germination success of seeds which they either defecate or regurgitate, as the gastrointestinal enzymes and acids within the gut of the birds soften the hard seed coat, thus breaking dormancy in seeds (Fleming and Heithaus 1981). Our study has clearly established the role played by birds in enhancement of seed germination in Dry Mixed Deciduous and Semi-evergreen Forests of the Western Ghats. Seeds of *Olea dioica*, *Persea macrantha* (both in Semi-evergreen Forest), *Ficus benghalensis*, *F. racemosa*, *Celtis philippensis*, *Cassine glauca* and *Strychnos potatorum* (Dry Mixed Deciduous Forest) showed significant enhancement in germination after passing through the guts of birds. Similar results have been reported by Midya and Brahmachary (1991) for *Ficus benghalensis* (58% germination in bird-dispersed seeds against 34% in control seeds), and by Mishra *et al.* (1987) for *Azadirachta indica* (76% germination in bird-dispersed seeds against 42% in control seeds). In South Australia, Yan (1993) observed more than 90% germination of mistletoe (*Amyema preissii* and *Lysiama excocarpi*) seeds dispersed by birds.

Though ficuses occur in low abundance, they play a very prominent role in sustaining frugivorous populations in tropical forests. Being aseasonal in fruit production, figs have evolved as one of the most reliable diet resources for the vertebrate community. The role of plant taxa that fruit in times of scarcity, in maintaining the population of the frugivore community was first propounded by Terborgh (1986), followed by Lambert and Marshall (1991). According to them, the abundance of fruiting in figs outside the peak fruiting season of the community, is the single factor that supports frugivorous communities in tropical forests. Due to this key role played by such taxa in the maintenance of community structure, they have been christened as 'keystone species.' At least 25 species of figs in the southern Western Ghats (Plate 1, Fig. 2) support the frugivorous bird community there, which in turn enhances germination and regeneration of bird-dispersed plant species. This augurs well for the sustenance of the forest ecosystem in the region.

CONCLUSION

Birds help determine the structure of tropical forests, as a major proportion of plant species are consumed and dispersed by them. As seen in this study, 73.7% of species in Tropical Dry Evergreen Forests of Point Calimere, 50% of species in Dry Mixed Deciduous Forests of Coimbatore Forest Division, Western Ghats, and 55.7% of species in Semi-evergreen Forest in Mudumalai Wildlife Sanctuary are bird-dispersed. Dispersion of seeds by birds was also seen in 35-70% of woody plants in Australian Wet Tropical and Dry Tropical Forests, and 47-54% of woody plants in North American Deciduous Forest and 49-66% in Mediterranean scrublands. Furthermore, seeds egested by birds have improved germination and regeneration vigour, thus increasing the dependence of plants on birds as a reliable and effective mode of dispersal. Thus birds have a pivotal role in shaping the structure of the forest. Plant communities in the present era have survived on account of their ability to interact mutualistically with birds.

Seed dispersal and regeneration are two processes that are absolutely indispensable to the maintenance of tropical forests (Galetti 2000, Herrera 1984, 1995, Howe 1984, 1990, Stiles 1985, 1992, Willson 1992). In spite of their fundamental importance in sustenance of tropical forests, very little is known about the role played by dispersers and the mechanism of dispersal. Research initiatives have been few and far between in the tropics and are mostly restricted to the Neotropics (Howe 1983, 1985, 1986, Howe and Vande Kerckhove 1981). Far greater efforts are needed to show the effectiveness of frugivores in dispersal and regeneration.

Though information is available for a few species, community-wide assessments of dispersers are negligible. Documentation of frugivory is only the first step in understanding the complex and manifold interactions between birds and plants. Being mobile links in tropical forest ecosystems, frugivores deserve greater attention, especially on the intricacies of their role in enhancement of germination and forest regeneration.

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Appendix I: Frugivorous birds of south Indian forests

Species	Common name	Body mass (g)	Feeding guild
COLUMBIDAE			
Chalcophaps indica	Emerald dove	144	G
Columba elphinstonii	Nilgiri wood-pigeon	379	F
Ducula badia	Mountain Imperial-Pigeon	580	F
Streptopelia decaocto	Eurasian collared-dove	210	G
Streptopelia chinensis	Spotted dove	128	G
Treron bicincta	Orange-breasted green-pigeon	128	F
Treron pompadora	Pompadour green-pigeon	151	F
PSITTACIDAE			
Loriculus vernalis	Indian hanging-parrot	50	G
Psittacula columboides	Blue-winged parakeet	100	G
Psittacula cyanocephala	Plum-headed parakeet	70	G
Psittacula eupatria	Alexandrine parakeet	225	G
Psittacula krameri	Rose-ringed parakeet	139	G
CUCULIDAE			
Clamator jacobinus	Pied crested cuckoo	74	I
Hierococcyx varius	Brainfever bird	104	I
Eudynamys scolopacea	Asian koel	167	F
Phaenicophaeus viridirostris	Small green-billed malkoha	114	I
TROGONIDAE			
Harpactes fasciatus	Malabar trogon	64	I
BUCEROTIDAE			
Anthracoceros coronatus	Malabar pied hornbill	1,000	F
Buceros bicornis	Great pied hornbill	2,500	F
Ocyceros griseus	Malabar grey hornbill	238	F
Ocyceros birostris	Indian grey hornbill	200	F
CAPITONIDAE			
Megalaima asiatica	Blue-throated barbet	100	F
Megalaima haemacephala	Coppersmith barbet	38	F
Megalaima rubricapilla	Crimson-throated barbet	47	F
Megalaima viridis	White-cheeked barbet	80.5	F
Megalaima zeylanica	Brown-headed barbet	87	F
ORIOLIDAE			
Oriolus oriolus	Eurasian golden oriole	65	I
Oriolus xanthornus	Black-headed oriole	79	I
STURNIDAE			
Acridotheres fuscus	Jungle myna	94	F
Acridotheres tristis	Common myna	98	I
Gracula religiosa	Hill myna	126	F
Sturnus malabaricus	Grey-headed starling	44	F
Sturnus pagodarum	Brahminy starling	54	F
Sturnus roseus	Rosy starling	75	F
CORVIDAE			
Corvus macrorhynchos	Jungle crow	650	O
Corvus splendens	House crow	280	O
Dendrocitta leucogastra	White-bellied treepie	95	F
Dendrocitta vagabunda	Indian treepie	128	F
CAMPEPHAGIDAE			
Coracina melanoptera	Black-headed cuckoo-shrike	36	I
Coracina macei	Large cuckoo-shrike	36	I

Appendix I: Frugivorous birds of south Indian forests (*contd.*)

Species	Common name	Body mass (g)	Feeding guild
IRENIDAE			
Aegithina tiphia	Common iora	14	I
Chloropsis aurifrons	Gold-fronted chloropsis	29	F
Chloropsis cochinchinensis	Jerdon's chloropsis	35	I
Irena puella	Asian fairy bluebird	30	F
PYCNONOTIDAE			
Iole indica	Yellow-browed Bulbul	31.5	F
Hypsipetes leucocephalus	Black bulbul	35	F
Pycnonotus cafer	Red-vented bulbul	35	F
Pycnonotus jocosus	Red-whiskered bulbul	35	F
Pycnonotus leucotis	White-eared bulbul	35	F
Pycnonotus luteolus	White-browed bulbul	35	F
Pycnonotus priocephalus	Grey-headed bulbul	35	F
Pycnonotus xantholaemus	Yellow-throated bulbul	32	F
MUSCICAPIDAE			
Acrocephalus dumetorum	Blyth's reed warbler	12	I
Copsychus saularis	Oriental magpie-robin	12	I
Parus major	Great tit	11.9	I
Sylvia curruca	Common lesser whitethroat	12	I
Turdoides caudatus	Common babbler	40	I
Turdoides striatus	Jungle babbler	77	I
Turdoides subrufus	Indian rufous babbler	67.5	I
DICAEIDAE			
Dicaeum agile	Thick-billed flowerpecker	9.5	F
Dicaeum concolor	Plain flowerpecker	6	F
Dicaeum erythrorhynchos	Tickell's flowerpecker	6.2	F
NECTARINIIDAE			
Nectarinia asiatica	Purple sunbird	7.5	N
Nectarinia lotenia	Loten's sunbird	9.5	N
Nectarinia zeylonica	Purple-rumped sunbird	5	N
ZOSTEROPIDAE			
Zosterops palpebrosus	Oriental white-eye	5.5	I

F= Frugivore; G = Granivore; I = Insectivore; N = Nectarivore and O = Omnivore
Feeding guilds are described based on Ali and Ripley (1983).

Appendix II: Bird-dispersed plant species in south Indian forests

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
ANACARDIACEAE			
Lannea coromandelica	Drupe	Brown	0.94
ANNONACEAE			
Alphonsea zeylanica	Carpel	Yellow	2.93
Alphonsea lutea	Carpel	Yellow	3.51
Alphonsea sclerocarpa	Carpel	Yellow	1.50
Goniothalamus wightii	Carpel	Black	1.54
Meiogyne pannosa	Carpel	Black	1.60
Orophea uniflora	Carpel	Black	1.17
Polyalthia cerasoides	Carpel	Red	0.77
Polyalthia coffeoides	Carpel	Red	2.34

Appendix II: Bird-dispersed plant species in south Indian forests (*contd.*)

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
Polyalthia longifolia	Carpel	Red	2.00
APOCYNACEAE			
Carissa carandas	Berry	Black	0.59
Carissa spinarum	Berry	Black	0.70
Tabernaemontana heyneana	Follicle	Red	0.94
ARECACEAE			
Bentinckia condapanna	Drupe	Black	1.40
Calamus rotang	Drupe	Yellow	1.40
Calamus viminalis	Drupe	Yellow	0.94
Caryota urens	Drupe	Red	2.50
Phoenix pusilla	Berry	Black	2.50
Phoenix sylvestris	Berry	Black	2.90
BISCHOFIACEAE			
Bischofia javanica	Berry	Black	1.00
BURSERACEAE			
Canarium strictum	Drupe	Black	4.00
CACTACEAE			
Opuntia stricta	Berry	Red	1.00
CAPPARACEAE			
Capparis brevispina	Berry	Red	3.50
Capparis grandis	Berry	Red	2.34
Capparis sepiaria	Berry	Blue	1.17
Capparis zeylanica	Berry	Red	4.50
Crateva adansonii	Berry	Red	2.00
Crateva magna	Berry	Red	3.51
CAPRIFOLIACEAE			
Viburnum punctatum	Drupe	Black	1.76
CELASTRACEAE			
Cassine glauca (Rottb.)	Capsule	Black	1.00
Euonymus indicus	Capsule	Black	1.76
Maytenus emarginata	Capsule	Red	0.77
Maytenus wallichiana	Capsule	Red	1.20
Pleurostylia opposita	Capsule	White	0.40
CLUSIACEAE			
Garcinia indica	Berry	Black	5.00
CONNARACEAE			
Connarus wightii	Follicle	Black	3.51
CORDIACEAE			
Carmona retusa	Drupe	Black	0.94
Cordia obliqua	Drupe	Yellow	1.17
Cordia wallichii	Drupe	Yellow	1.17
CUCURBITACEAE			
Coccinia grandis	Berry	Red	2.50
Mukia maderaspatana	Berry	Red	1.17
Trichosanthes cucumerina	Berry	Red	2.50
Trichosanthes tricuspidata	Berry	Red	1.50
DAPHNIPHYLLACEAE			
Daphniphyllum sp.	Drupe	Red	1.25
EBENACEAE			
Diospyros ferrea (Willd.)	Berry	Red	1.20
Diospyros melanoxylon	Berry	Yellow	1.76

Appendix II: Bird-dispersed plant species in south Indian forests (*contd.*)

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
Diospyros montana	Berry	Yellow	1.76
Diospyros oocarpa	Berry	Yellow	2.34
EHRETIACEAE			
Ehretia ovalifolia	Drupe	Red	1.17
ELAEOCARPACEAE			
Elaeocarpus serratus	Drupe	Yellow	3.51
ERICACEAE			
Gaultheria fragratissima	Capsule	Black	1.17
ERYTHROXYLACEAE			
Erythroxylum monogynum	Drupe	Black	0.77
EUPHORBIACEAE			
Antidesma menasu	Drupe	Black	0.59
Aporosa lindleyana	Capsule	Black	0.94
Breynia vitis-idaea	Capsule	Black	1.17
Bridelia crenulata	Drupe	Red	0.80
Drypetes roxburghii	Drupe	Red	2.80
Drypetes sepiaria	Drupe	Red	1.17
Glochidion velutinum	Capsule	Red	1.17
Macaranga peltata	Capsule	Orange	1.25
Mallotus ferrugineus	Capsule	Black	0.80
Mallotus philippensis	Capsule	Red	1.17
Phyllanthus reticulatus	Berry	Black	2.50
Securinega leucopyrus	Capsule	White	0.37
Securinega virosa	Capsule	White	0.94
FLACOURTIACEAE			
Casearia elliptica	Capsule	Red	1.76
Casearia ovata	Capsule	Yellow	1.50
Flacourtia indica	Berry	Black	1.76
Flacourtia montana	Berry	Red	2.34
Scolopia crenata	Drupe	Black	0.75
Xylosma latifolium	Drupe	Black	0.75
GNETACEAE			
Gnetum ula	Drupe	Orange	2.81
HIPPOCRATEACEAE			
Salacia chinensis	Berry	Red	1.76
ICACINACEAE			
Gomphandra tetrandra	Drupe	Black	1.17
Gomphandra coriacea	Drupe	Black	1.75
Nothapodytes nimmoniana	Drupe	Black	1.75
LAURACEAE			
Actinodaphne bourdillonii	Berry	Black	1.50
Actinodaphne malabarica	Berry	Black	1.17
Alseodaphne semecarpifolia	Berry	Black	0.77
Apollonias arnottii	Berry	Black	0.59
Beilschmiedia wightii	Berry	Black	0.77
Cassytha filiformis	Berry	Black	0.94
Cinnamomum filipedicellatum	Berry	Black	1.25
Cinnamomum sulphuratum	Berry	Black	1.25
Cinnamomum travancoricum	Berry	Black	1.25
Cinnamomum verum	Berry	Black	1.50
Cryptocarya bourdillonii	Berry	Black	1.20

Appendix II: Bird-dispersed plant species in south Indian forests (*contd.*)

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
Cryptocarya lawsonii	Berry	Black	1.25
Litsea glabrata	Berry	Black	1.25
Litsea insignis	Berry	Black	1.25
Litsea mysorensis	Berry	Black	1.00
Litsea stocksii	Berry	Black	1.25
Litsea wightiana	Berry	Black	1.25
Neolitsea cassia	Berry	Black	1.25
Neolitsea fischeri	Berry	Black	0.70
Persea macrantha	Berry	Black	1.76
Phoebe lanceolata	Berry	Black	1.51
LEEACEAE			
Leea indica	Berry	Black	0.23
LILIACEAE			
Asparagus racemosus	Berry	Red	0.50
LINACEAE			
Hugonia mystax	Drupe	Red	1.76
LOGANIACEAE			
Fagraea ceilanica	Berry	Black	3.50
Strychnos nux-vomica	Berry	Red	3.50
Strychnos potatorum	Berry	Black	2.81
LORANTHACEAE			
Dendrophthoe falcata	Berry	Orange	0.94
Viscum capitellatum	Berry	Green	0.94
Viscum orientale	Berry	Black	0.94
MAGNOLIACEAE			
Michelia champaca	Carpel	Brown	3.50
Michelia nilagirica	Carpel	Brown	2.50
MELASTOMATACEAE			
Memecylon malabaricum	Berry	Blue	1.50
Memecylon molestum	Berry	Blue	1.10
Memecylon umbellatum	Berry	Blue	1.10
MELIACEAE			
Aglaia elaeagnoidea	Drupe	Yellow	1.76
Aphanamixis polystachya	Capsule	Red	1.87
Azadirachta indica	Drupe	Yellow	1.76
Cipadessa baccifera	Drupe	Red	0.59
Dysoxylum malabaricum	Drupe	Red	4.68
Melia azaderach	Drupe	Yellow	1.76
Melia dubia	Drupe	Yellow	1.17
Trichilia connaroides	Capsule	Black	1.17
Walsura trifoliata (Juss.)	Berry	Brown	0.59
MELIOSMACEAE			
Meliosma simplicifolia	Drupe	Red	1.20
MENISPERMACEAE			
Cocculus hirsutus	Drupe	Red	2.34
Pachygone ovata (Poir.)	Drupe	Red	0.70
Tinospora cordifolia	Drupe	Red	1.20
MORACEAE			
Ficus amplissima	Syconium	White	1.00
Ficus benghalensis	Syconium	Red	1.17
Ficus drupacea	Syconium	Orange	2.93

Appendix II: Bird-dispersed plant species in south Indian forests (*contd.*)

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
Ficus microcarpa	Syconium	Yellow	0.25
Ficus mollis	Syconium	Yellow	0.70
Ficus religiosa	Syconium	Yellow	1.17
Ficus tsjahela	Syconium	Green	0.59
Ficus virens	Syconium	Green	0.47
Plecospermum spinosum	Achene	Yellow	0.50
Streblus asper	Syconium	Yellow	1.40
MYRISTICACEAE			
Knema attenuata	Capsule	Red	3.51
Myristica dactyloides	Capsule	Red	3.50
MYRSINACEAE			
Ardisia amplexicaulis	Berry	Red	0.94
Ardisia rhomboidea	Berry	Red	0.94
Embelia adnata	Berry	Red	1.17
Embelia ribes	Berry	Red	0.29
Maesa dubia	Berry	Red	1.17
Maesa perrottetiana	Berry	White	1.17
Maesa velutina	Berry	Red	1.17
Rapanea wightiana	Berry	Red	1.17
MYRTACEAE			
Eugenia argentea	Berry	Black	1.40
Eugenia discifera	Berry	Black	0.59
Eugenia floccosa	Berry	Black	1.17
Eugenia indica(Wt.)	Berry	Black	0.47
Eugenia thwaitesii	Berry	Red	1.25
Syzygium cumini (L.)	Berry	Black	1.64
Syzygium gardneri	Berry	Black	1.25
Syzygium travancoricum	Berry	Black	1.25
OCHNACEAE			
Ochna obtusata	Drupe	Black	0.59
OLACACEAE			
Olax scandens	Drupe	Yellow	0.94
OLEACEAE			
Jasminum angustifolium	Drupe	Black	0.59
Jasminum auriculatum	Drupe	Black	0.47
Olea dioica	Drupe	Black	0.94
Olea glandulifera	Drupe	Black	0.94
OPILIACEAE			
Cansjera rheedii	Drupe	Red	1.76
PASSIFLORACEAE			
Passiflora foetida	Berry	Yellow	1.50
Passiflora leschenaultii	Berry	Yellow	1.76
PROTEACEAE			
Helicia nilagirica	Nut	Black	1.00
RHAMNACEAE			
Rhamnus virgata	Drupe	Yellow	1.17
Scutia myrtina	Drupe	Blue	1.17
Zizyphus glabrata	Drupe	Orange	0.59
Zizyphus mauritiana	Drupe	Yellow	1.00
Zizyphus oenoplia	Drupe	Yellow	0.60
Zizyphus rugosa	Drupe	Yellow	0.70

Appendix II: Bird-dispersed plant species in south Indian forests (*contd.*)

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
ROSACEAE			
Photinia integrifolia	Berry	Red	0.50
Rubus fulvus	Drupe	Red	0.80
RUBIACEAE			
Benkara malabarica	Drupe	Black	1.76
Canthium dicoccum	Drupe	Black	1.76
Canthium parviflorum	Drupe	Black	1.76
Gardenia latifolia	Berry	Green	2.50
Ixora nigricans	Drupe	Black	1.25
Ixora pavetta	Drupe	Black	1.76
Morinda coreia	Drupe	Black	1.76
Octotropis travancorica	Berry	Black	1.50
Pavetta breviflora	Drupe	Black	1.76
Pavetta indica	Drupe	Black	1.76
Pavetta thomsonii	Drupe	Black	1.50
Tricalysia apiocarpa	Berry	Black	0.90
RUTACEAE			
Clausena dentata	Berry	Black	0.94
Glycosmis pentaphylla	Berry	Yellow	0.94
Melicope indica	Berry	Yellow	0.94
Murraya koenigii	Berry	Black	0.94
Naringi crenulata	Berry	Yellow	0.70
Toddalia asiatica	Berry	Yellow	1.40
SALVADORACEAE			
Azima tetracantha	Berry	Black	0.94
Salvadora persica	Drupe	Black	0.94
SANTALINACEAE			
Santalum album	Drupe	Black	0.94
SAPINDACEAE			
Allophyllus cobbe	Drupe	Black	0.94
Filicium decipiens	Drupe	Black	1.17
Lepisanthes tetraphylla	Drupe	Black	0.94
Schleichera oleosa	Drupe	Yellow	1.87
SAPOTACEAE			
Donella roxburghii	Berry	Yellow	2.93
Isonandra lanceolata	Berry	Red	2.00
Madhuca longifolia	Berry	Green	2.93
Manilkara hexandra	Berry	Yellow	1.17
Manilkara roxburghiana	Berry	Yellow	1.76
Mimusops elengi	Berry	Red	2.34
Xantolis tomentosa	Berry	Yellow	2.34
SMILACACEAE			
Smilax zeylanica	Drupe	Yellow	1.10
SOLANACEAE			
Solanum pubescens	Berry	Red	0.70
Solanum trilobatum	Berry	Red	0.94
THEACEAE			
Ternstroemia japonica	Berry	Red	1.20
TILIACEAE			
Grewia hirsuta	Drupe	Brown	0.80
Grewia obtusa	Drupe	Brown	0.59

Appendix II: Bird-dispersed plant species in south Indian forests (*contd.*)

Species	Fruit type	Ripe fruit colour	Fruit size (cm)
Grewia orbiculata	Drupe	Black	0.70
Grewia ovalifolia	Drupe	Brown	0.59
Grewia rhamnifolia	Drupe	Brown	0.35
Grewia tiliifolia	Drupe	Black	0.59
ULMACEAE			
Celtis philippensis	Drupe	Red	0.94
Trema orientalis	Drupe	Black	0.59
VERBENACEAE			
Lantana camara	Drupe	Black	0.23
Premna serratifolia	Drupe	Yellow	0.23
Vitex altissima	Drupe	Black	0.47
VITACEAE			
Cissus quadrangularis	Berry	Black	0.23
Cissus vitigenia	Berry	Black	0.35

Sources: Balasubramanian 1996, Balasubramanian and Maheswaran 2001, Balasubramanian *et al.* 1998, Ganesh and Davidar 2001, Kannan and James 1999.

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CROCODILE CONSERVATION, WESTERN ASIA REGION: AN UPDATE

(*With three text-figures and two plates*)

Romulus Whitaker[1] and Harry V. Andrews[2]

Key words: Crocodiles, conservation, South Asia, gharial, mugger, saltwater crocodile

Crocodile conservation began in earnest in the mid 1970s when all the three South Asian species — the gharial (*Gavialis gangeticus*), mugger (*Crocodylus palustris*) and saltwater crocodile (*Crocodylus porosus*) were near extinction. The Government of India assisted by FAO/UNDP eventually established 13 sanctuaries for crocodile conservation in India and thousands of gharial, mugger and saltwater crocodiles, reared from wild collected eggs, were released in the wild. Unfortunately, the energy and enthusiasm for crocodile conservation has all but vanished. Sri Lanka has more wild mugger than the rest of South Asia combined and a small mugger population survives in Iran. Pakistan and Nepal have very few mugger and gharial left, while in Bhutan they are all but extinct.

The Madras Crocodile Bank houses the largest gene pool of mugger as well as breeding groups of gharial and saltwater crocodiles.

Conservation of crocodiles in South Asia through sustainable use is seen as the strategy that could save the three species in the long run, since protection on paper does not appear to be working.

INTRODUCTION

At the best of times in human history, crocodiles have not been very popular. True, they appear in myth and religion: Ma Ganga, the Ganga river goddess, rides a mugger and the crocodile monster is Makara, the carrier of Varuna the rain god. Yet, then as now, the crocodile was feared, reviled and killed when possible — and killed they were — throughout the Indian subcontinent, the Andaman and Nicobar Islands and Sri Lanka. Some of us did surveys in the early 1970s and confirmed reports from even the remotest areas that India's three crocodilians were indeed going extinct, due to hunting and habitat loss (Biswas 1970, Whitaker 1974a, b, Whitaker and Daniel 1980). In the mid 1970s, two initiatives were made toward saving the gharial *Gavialis gangeticus*, the mugger *Crocodylus palustris* and the saltwater crocodile *Crocodylus porosus*. One was the large-scale GOI/FAO/UNDP Crocodile Conservation Project that covered all crocodilian states in India, and the other was a private trust, the Madras Crocodile Bank.

Thanks to the work, interest and enthusiasm of an array of people from skilled boatmen to unfortunate bureaucrats behind desks, from keen young students and forest officers to overseas consultants and Ph.D. scholars, India's three spectacular crocodilians were yanked back virtually from the brink. This was one of the world's conservation success stories. Now it is time to evaluate what the Project achieved and why it came to a grinding halt.

THE INDIAN CROCODILE CONSERVATION PROJECT

In 1974, a consultant from the Food and Agriculture Organization (FAO) of the United Nations Development Programme (UNDP), H.R. Bustard was invited by the Government of India (GOI) to look at the crocodile situation in India (Bustard 1974). Backed by survey reports by Indian workers, Bustard drafted an FAO project document for the GOI, that spelled out an egg collection, rear and release programme with a plan to establish protected areas at suitable locations. The project included research, training and even involvement

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of the local people to protect their interests and to include them in village level commercial crocodile farming and ranching (Singh 1999a).

Since the project began more than 25 years ago, thousands of gharial, mugger and salties have been reared, mainly from wild collected eggs, at special rearing centres. As a result of the GOI/FAO/UNDP Project, 13 sanctuaries totalling over 8,000 sq. km were created for crocodile conservation in India. Twenty-one other protected areas provide incidental protection to remnant natural populations and restocked crocodiles. Over nine thousand gharial, mugger and saltwater crocodiles have been released at more than 30 sites throughout the country.

Results of the releases have been mixed. For example, most of the 142 mugger released in Krishnagiri Reservoir, Tamil Nadu in 1985 were killed off within 2 years (V.M. Narasimhan, pers. comm.). Of the 150 mugger released in the Anamalai Wildlife Sanctuary, only three animals were traceable by 1992 (Choudhury 1986, Satheesh 1992, Andrews 1999b). The 700 juvenile gharial released in the Satkosia Gorge Sanctuary on Mahanadi river in Orissa mostly vanished (Singh 1991, 1999b). The saltwater crocodiles released in Andhra Pradesh during 1978 also vanished due to anthropogenic pressures (Srinivas *et al.* 1999). On the other hand, gharial releases in the Chambal river and saltwater crocodile releases in Bhitarkanika have been successful.

Gharial

This unique species, once almost on the verge of extinction, has made a major comeback since the 1980s. Whitaker and Basu (1979) estimated less than a hundred gharial (*Gavialis gangeticus*) in the wild. Since then, of the 4,330 gharial reared at Kukrail centres in Uttar Pradesh state, 3,495 were released (Singh *et al.* 1999). In Madhya Pradesh, 250 have been released since 1985 into the Chambal, Ken and Son river systems. During the 1995-1997 surveys of the National Chambal Sanctuary (Rajasthan, Madhya Pradesh and Uttar Pradesh) 1,214 gharial were counted, with an adult (Plate 1, Fig. 1) male to female ratio of 1:3.6. A total of 75 nests were also located, all of which indicates that the gharial population is recovering (Rao *et al.* 1995, Rao 1999, Sharma 1999). The current gharial status is shown in Table 1. Next to the Chambal Sanctuary, Katerniaghat Sanctuary, also in Uttar Pradesh, has the second largest wild gharial population. However, this population is currently facing the threat of extinction due to habitat pressure and inadequate recruitment. The remaining gharial sites in India have 50 or fewer animals.

In particular, the new Indian state of Uttaranchal, along with Rajasthan and Madhya Pradesh hold the world responsibility of the welfare of the largest wild gharial population. The Chambal river is the last bastion of the gharial and a wide array of river life. Any designs to

Table 1: Total wild gharial in India

Location	Estimated numbers released	Estimated wild gharial
National Chambal Wildlife Sanctuary:		
Rajasthan = 0		
Madhya Pradesh = 57		
Uttar Pradesh = 3,495	3,552	1,240 (based on surveys)
Katerniaghat Sanctuary, Uttar Pradesh	?	100 (guesstimate)
Corbett National Park, Uttar Pradesh	?	30? (no recent data)
Ken/Son rivers, Madhya Pradesh	193	50 (based on surveys)
Arunachal Pradesh	?	10? (no recent data)
Orissa	700 +	35 (based on surveys)
Total	4,445 +	1,465 +/- 200

Source: ENVIS (Wildlife & Protected Areas) (2)1, 1999.

tamper with this river system for so-called "development" and "betterment of the people" must be thwarted.

In northeast India, gharial are near extinction, with an estimated population of 10 individuals (Choudhury 1997). The same author has reported breeding in isolated areas, besides individual specimen sightings in Siang, Subansiri and the Noa-Dihing rivers, tributaries of the Brahmaputra. There is an urgent need for conservation and management action in this state. Surplus gharial in captivity from the states of Uttar Pradesh or Orissa can be transported and released in protected areas such as D'Ering Memorial Sanctuary and Namdapha National Park, and an efficient monitoring system set in motion.

The West Bengal Forest Department has reintroduced gharial into Thorsa and Teesta rivers on an experimental basis, encouraged by historical accounts of the presence of this species in the state (Srinivas *et al.* 1999). The historical and current distributional range of the gharial is shown in Fig. 1.

Gharial outside India

In Nepal, gharial were once distributed throughout the width of the country in all the major river systems and their tributaries. Currently there are only small, isolated populations in the Karnali, Babai, and the Narayani river systems, all of which are in, or adjacent to, protected areas (Maskey and Mishra 1981, Andrews and McEachern 1994, Maskey 1999). Since 1981, 432 gharial have been released and 70 more in 1993 (Andrews and McEachern 1994, Maskey 1999). The current estimated population in the wild is 105 individuals distributed in seven rivers (Maskey 1999). Conservation efforts started in 1978 are still under way through an egg collection, rear and release programme.

The gharial populations in Pakistan, Bhutan, and Bangladesh are near extinct and probably not viable. Estimated populations are 10-15 in Pakistan, around 5 in Bhutan and 5-10 in Bangladesh. The gharial is extinct in Myanmar; one was shot on the Maingtha river in 'Upper Burma' in 1929 (Smith 1931).

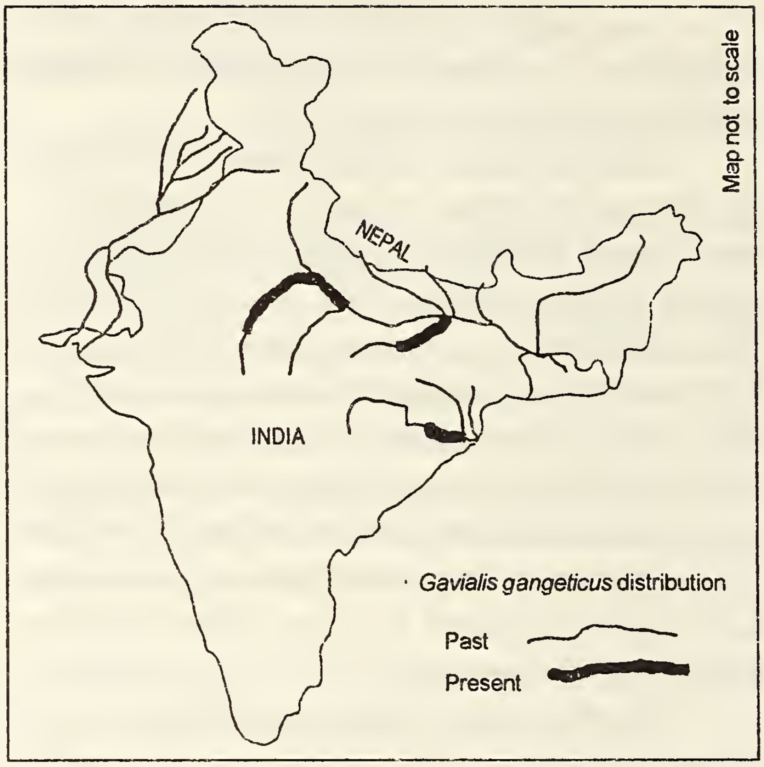

Fig. 1: Historical range and current distribution of the gharial within the Indian subcontinent

MUGGER

The mugger (Plate 1, Fig. 2) *Crocodylus palustris* is the most adaptable of the three Indian crocodilians and has been encountered up to 400 m in crystal clear hill streams, sewage treatment ponds, cold deep rivers in the Himalayan foothills, oxbow lakes in Nepal and saltpans in southern Sri Lanka. The current and historical range of the mugger is shown in Fig. 2. Surveys in the early 1970s identified Gujarat and Tamil Nadu (two of India's drier states) as having most of India's mugger (Whitaker 1987). The present estimated wild mugger population in Tamil Nadu is 465, of which 52% are adults (Andrews 1999b). The reported population for Gujarat is 429 individuals with 88% adults (Vijaya Kumar *et al.* 1999).

Tamil Nadu and Gujarat are the most completely surveyed states for mugger and a look at the comparative data on croc numbers for the

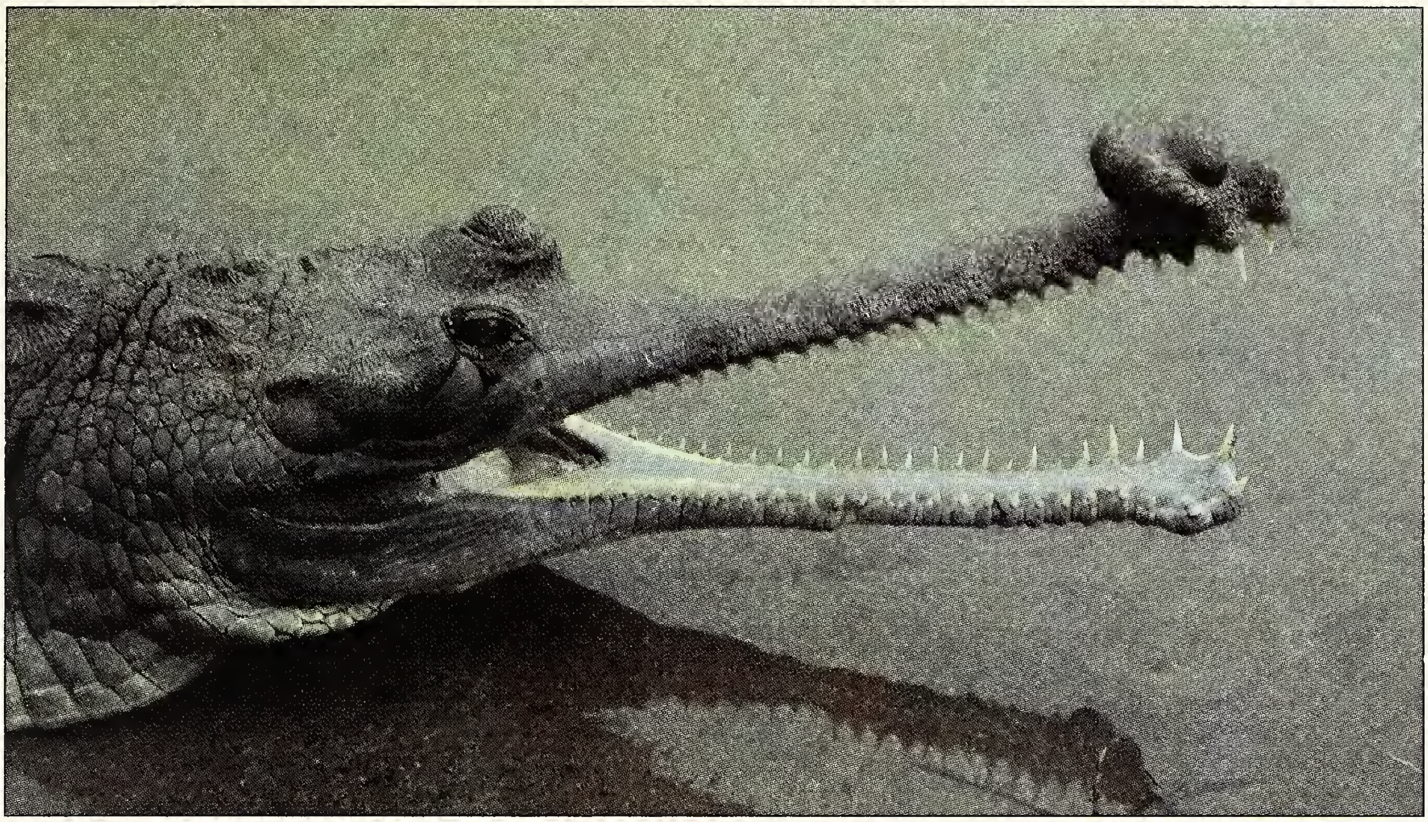

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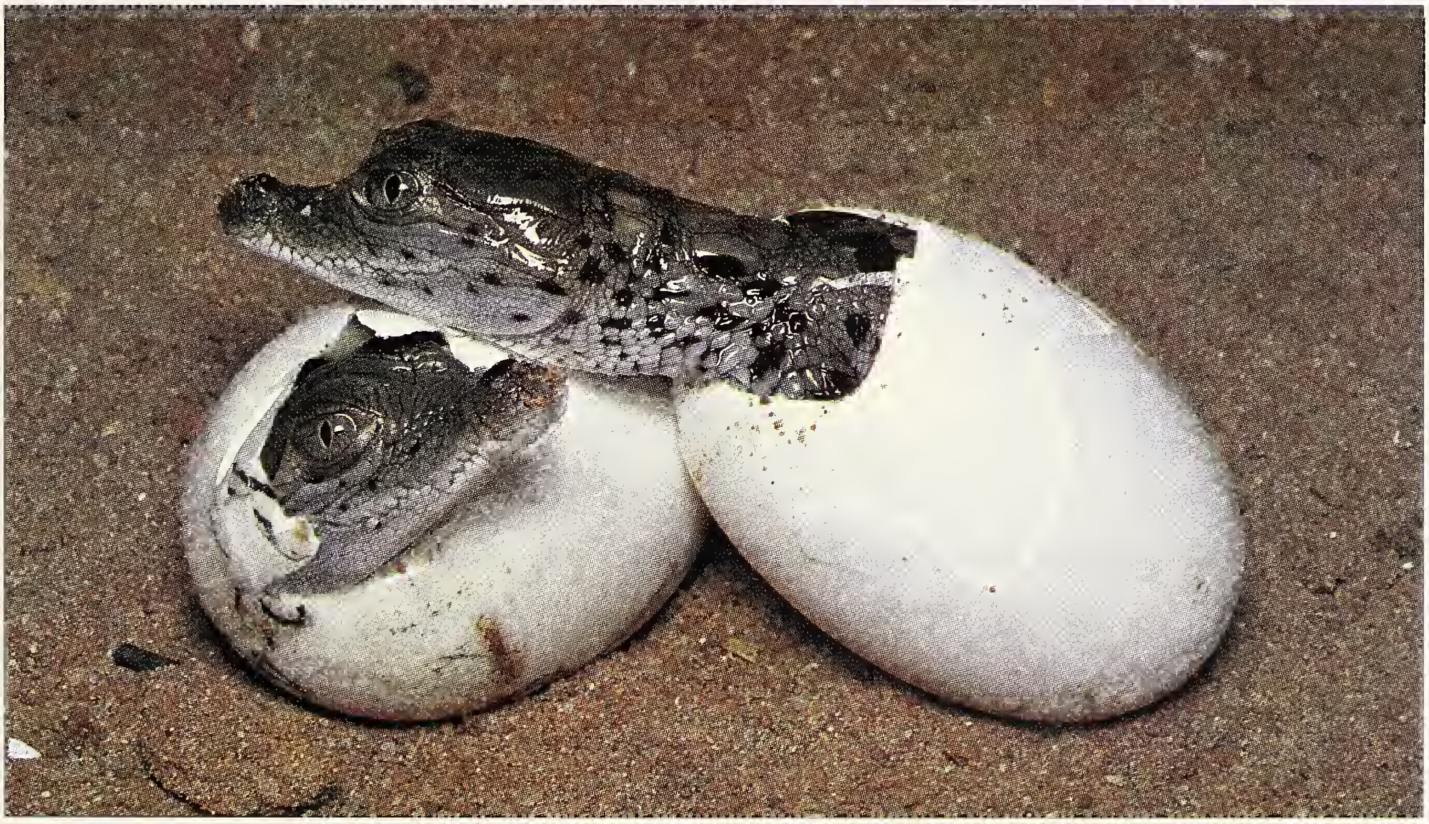
Fig. 1: Male gharial *Gavialis gangeticus* showing the 'ghara' of a mature animal



BELINDA WRIGHT

Fig. 2: Mugger *Crocodylus palustris* hatching

Whitaker, Romulus and Harry V. Andrews: South Asian crocodiles

PLATE 2

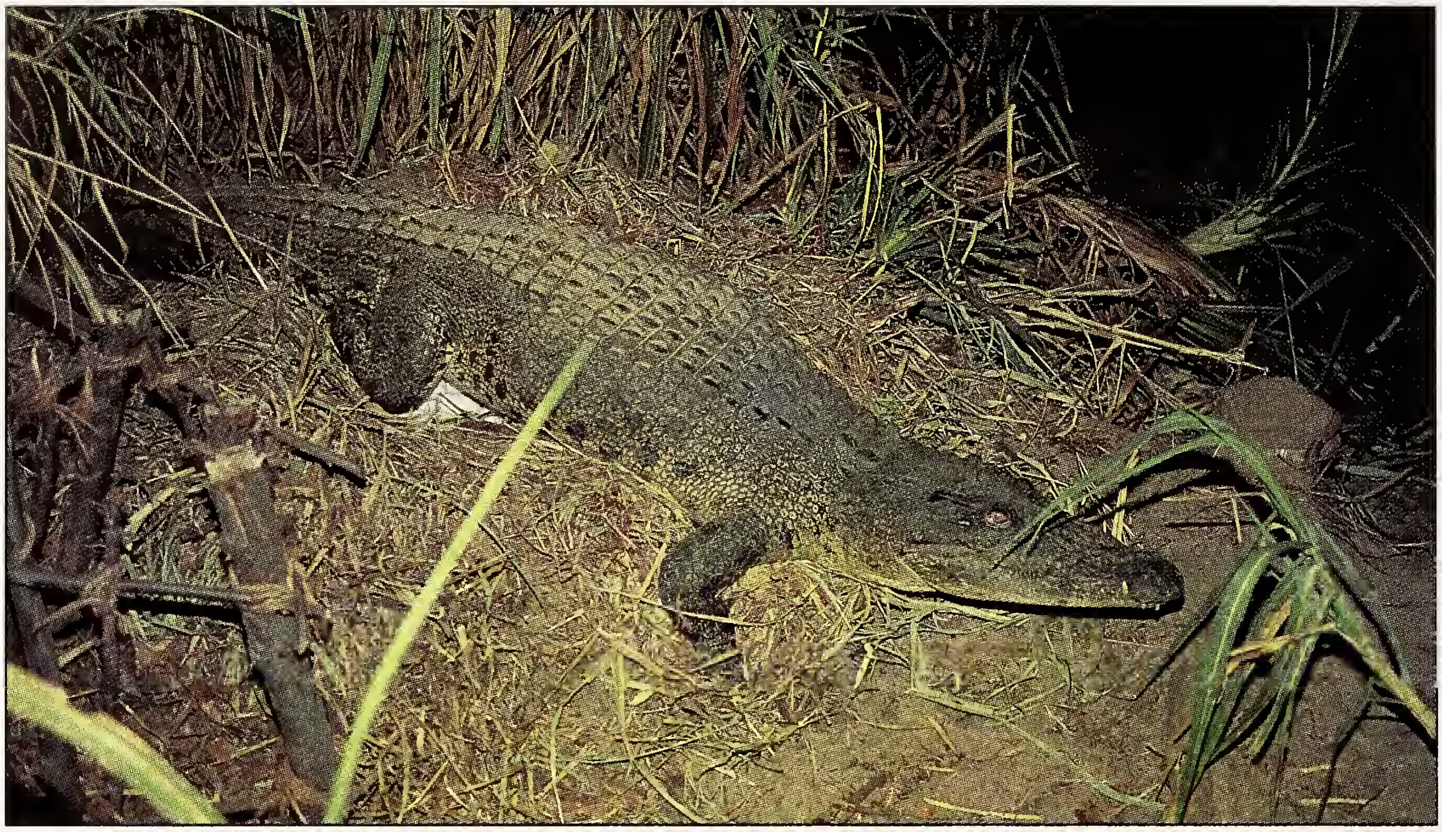


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Fig. 3: Saltwater crocodile *Crocodylus porosus* nesting

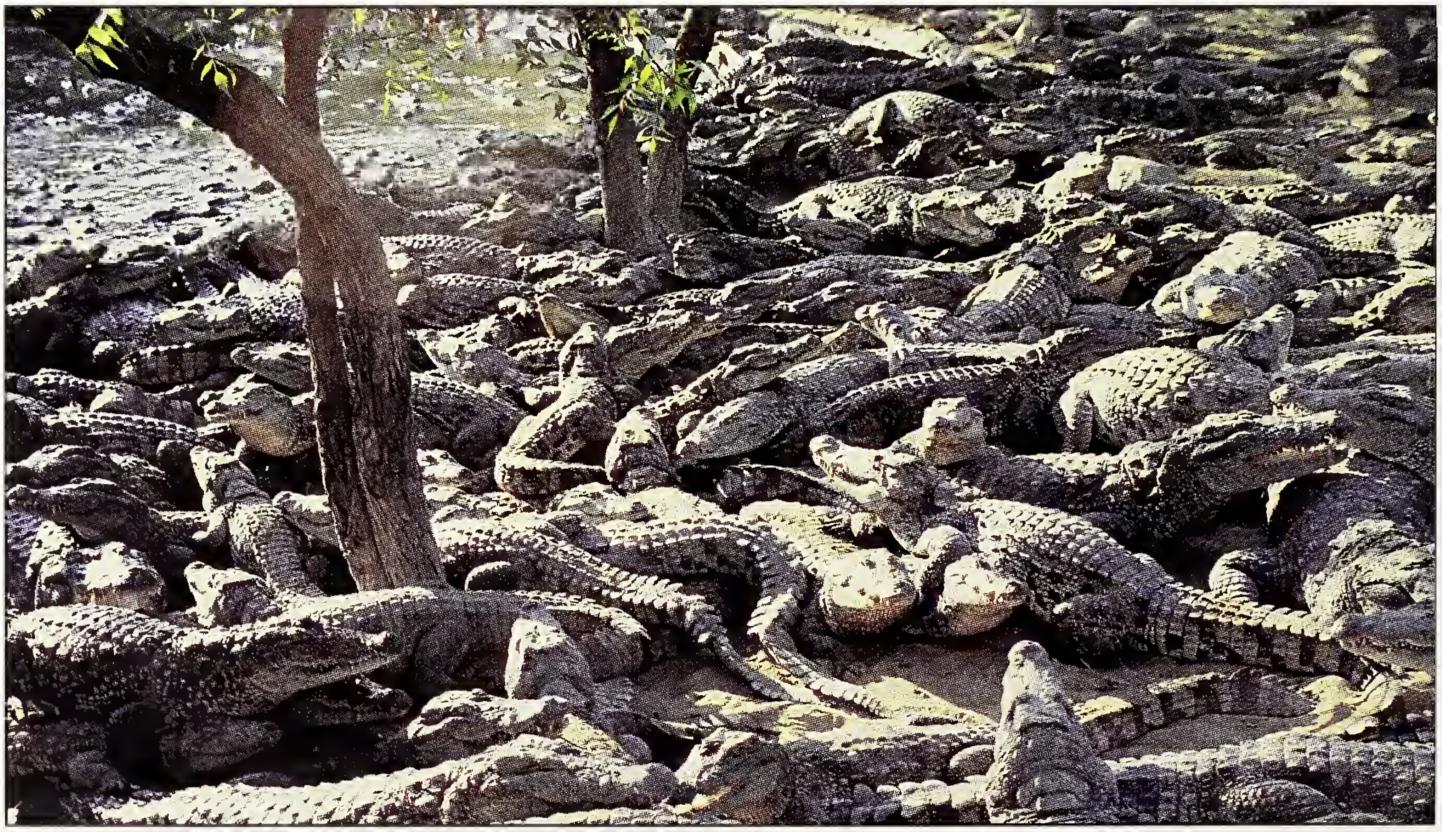

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Fig. 4: In India, most crocodiles are in captivity

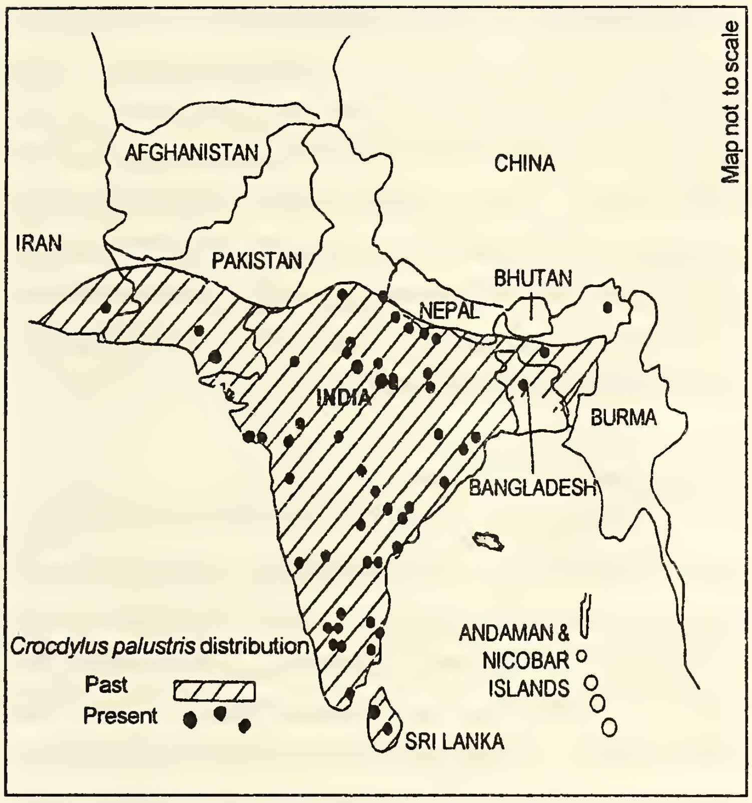

Fig. 2: Historical range and current distribution of the mugger within the Indian subcontinent

1970s and the 1990s reveals some definite trends. In general, mugger numbers have increased, due to restocking and protection, and in cases like the Moyar river in Tamil Nadu, simply by doing more complete surveys (Vijaya Kumar and Vyas 1997, Andrews 1999b).

There are fairly stable small mugger populations in the state of Karnataka along the Cauvery and Kabini rivers and in the Ranganathittu Bird Sanctuary. Ranganathittu has approximately 17-20 adults and 10-15 subadults; juveniles and hatchlings are also seen in this Sanctuary (Venugopal 2000). Along remote stretches of the Cauvery river, adult mugger are sporadically seen and the estimated total population along this river is 50 adults. The Kabini river (which originates in Kerala) flows through the Nagarhole National Park and has a small stable population within the protected area. During a preliminary survey, 22 adults were counted by direct sighting. The habitat is pristine, several mugger tunnels and good nesting banks were also observed within the Park (Andrews 1995). Other areas which reportedly have small mugger populations include the Tungabhadra Reservoir (Bhadra Sanctuary) and Shiva Samudram.

The state of Andhra Pradesh has been involved in crocodile conservation since 1976 and has released over 320 mugger in seven different localities (Vijaya Kumar and Choudhury 1990, Vijaya Kumar 1993, Srinivas *et al.* 1999). Isolated small populations occur in Manjira, Ethypothala and Siwaram Wildlife Sanctuaries, but their present status is unknown.

The estimated mugger population in Rajasthan is around 470, distributed in 11 protected areas (Sharma *et al.* 1999). Ranthambore National Park has the highest with 200 crocs and the National Chambal Wildlife Sanctuary has around 100. In the other protected areas numbers vary from 10-50 individuals. There are increasing reports of human - croc conflict from the Chambal area which calls for immediate education programmes and a Flying Squad to capture and translocate problem animals.

Mugger in Kerala are found in the Neyyar Reservoir, Parambikulam Reservoir and the Nugu and Kabini rivers. Conservation work was taken up during 1977 when the wild population in the State was less than 60, and releases have been done in Neyyar and in Parambikulam. The current estimated population is 259, based on the surveys of 1997 (Pillai 1999). The highest densities are in Neyyar and Parambikulam. The population in Parambikulam is stable and the habitat is still pristine (Andrews, pers. observ.). Currently Kerala has 192 mugger in captivity and has to deal with constant human - croc conflicts in Neyyar Reservoir. The Forest Department has started an education programme and the capture of large problem animals.

In Maharashtra, *C. palustris* were once abundant in all the major river systems and lakes, but were depleted by the 1960s (Gogate 1999). The first author remembers that, at Powai Lake in the late 1950s, a reward of Rs. 50 was offered for killing a crocodile and Rs. 10 for destroying a crocodile egg, probably by the Fisheries Department. A conservation programme was started in 1977 and reintroduction was carried out up to 1992 in and around protected areas, however there have been no surveys or monitoring, so no information on the current wild population is available.

In Goa, small breeding populations of mugger still exist in several parts, including Selaulim Dam, Opa river and small lakes in the Ciba-Geigy and IOAR compounds. The largest concentrations are found in the mangrove-lined brackish creeks of the Zuari and Cumbarjua rivers. While there has never been any formal release programme, 38 rescued mugger have been released here in the past few years. Unfortunately, crocs are killed by local fishermen and illegal clearance of mangroves has devastated the habitat of the mugger and a myriad other taxa (Alvares and D'Sousa, in press).

Perhaps the most remarkable feature of the mugger situation in India is that while there are less than 2,500 left in the wild (Table 2), there are over 3,000 in captivity at the various State Government rearing centres and at the Madras Crocodile Bank. Captive breeding and wild egg collection for rearing has been stopped since 1985, because suitable release sites are scarce and so are funds. The entire croc conservation programme came to a halt mainly because sustainable use of the mugger as a resource was not taken up, although it was one of the goals of the GOI/FAO/UNDP project.

Mugger outside India

Sri Lanka: Sri Lanka has a large mugger population probably numbering several thousand throughout the island nation (Whitaker and Whitaker 1979, Santiapillai *et al.* 2000). While the largest numbers occur in two national parks, Yala and Wilpattu, mugger can be seen in large tanks, in rice fields, waterways and small and large rivers in most sparsely populated areas. The mugger is strictly protected in Sri Lanka and a crocodile management and conservation project is being formulated (Whitaker, in prep.). A recent film on the mugger in Sri Lanka reveals unique underwater footage of breeding behaviour and parental care

Table 2: Total wild mugger in India

Location	Estimated numbers released	Estimated wild mugger
Orissa (Simlipal river systems)	350+	65 (based on surveys)
Gujarat	1,000+	429 (based on surveys)
Uttar Pradesh	?	200 (guesstimate)
Andhra Pradesh	320	100? (no recent data)
Tamil Nadu	350+	465 (based on surveys)
Rajasthan	?	470 (guesstimate)
Kerala	50+	259 (guesstimate)
Karnataka	?	150? (no recent data)
Madhya Pradesh	27	134 (based on surveys)
Maharashtra	200	100? (no recent data)
Goa	38	148 (based on surveys)
Haryana	?	20
Bihar	?	? (no recent data)
West Bengal	?	? (no recent data – likely extinct)
Northeastern states	?	? (no recent data)
Punjab	?	? (no recent data – likely extinct)
Jammu and Kashmir	?	? (no recent data – likely extinct)
Total	2,335	2,540 +/-300

Source: ENVIS (Wildlife & Protected Areas) (2)1, 1999; Vijaya Kumar and Vyas 1997; Alvares and D'Sousa, in press.

by the male. Sri Lanka holds the responsibility for the long-term survival of the mugger.

Iran: In Iran, a small number of muggers are hanging on by the skin of their teeth in the southeastern, Baluchestan region. Frazer (2000) has reported areas of riverine and estuarine wetlands, such as the Govater Bay and Hur-e-Bahu (which is a 75,000 ha Ramsar site), as important for *Crocodylus palustris*. Other areas include the Sarbaz and Kajou rivers, where muggers are protected by local folk beliefs (Kami and Saghari 1993). During 1992 surveys, 16 *gando* (= crocodile in Farsi) were counted in the Kajou river and 30 in the 16 adjacent ponds. During the same survey, 72 muggers were recorded in the Sarbaz river and adjacent ponds along it (Kami and Saghari 1994). Mobaraki (1998a) located nests in the Bahukalat Protected Region. Here muggers inhabit small streams and pools, and during the dry months, migrate across the border into Pakistan (Kami and Saghari 1993, Mobaraki 1998b). There is some Government interest in mugger conservation, and select areas are now protected. However, more recent information on current status is lacking.

Pakistan: The mugger of Pakistan was thought to be near extinct, with a few small isolated populations scattered in various areas (Khan 1993, 1994). A captive-breeding programme was started during 1993 and the Government of India supplied gharial and mugger for this programme. However, during 1999 surveys, an estimated population of 500-1,000 mugger has been reported for the Deh-Akro Wildlife Sanctuary in Sindh Province, which consists of 25 lakes formed by the seepage from irrigation channels. There are also reports of crocs in Hingol National Park, the largest park in Pakistan with an area of 619,043 ha (Chaudhury 2000). Currently all the major wetlands in Pakistan are threatened, thanks to the World Bank-aided 'National Drainage Programme' which involves construction of dams and channels, diversion of natural flows, and funnelling agricultural runoffs into river systems (Rose 1998, Chaudhury 2000).

Nepal: In Nepal, mugger have been reduced to small isolated populations mainly in protected areas, such as the Royal Sukla Phanta Wildlife Reserve, Bardia Reserve and the Royal Chitawan National Park. A small number have been reported from the Sapta Koshi area and the Lumbini district. The Mahakali and Bahuni rivers adjacent to Sukla Phanta represent excellent habitat and are contiguous with similar areas in Uttar Pradesh. Surveys by IUCN Nepal revealed depressed numbers in this area. The estimated wild population of mugger is around 200 (Andrews and McEachern 1994). Loss of habitat and construction of dams and barrages has affected *C. palustris* populations and recruitment in the wild. Each year, juveniles and hatchlings, flushed below the barrages (low dams), cannot return during the post monsoon season and usually perish. Conservation efforts in Nepal started in 1978 with wild gharial egg collection for rearing and release programmes. Releases started in 1981 and IUCN Nepal started a programme for mugger in 1992.

Bhutan: In Bhutan, mugger became extinct by the late 1960s and during 1981 a captive breeding programme was started at a centre at Phuentsholing. Mugger from Uttar Pradesh, India, were obtained for this purpose. In May 2000, there was a small group of 17 mugger breeding successfully, and 4 adult female gharial (Whitaker, pers. observ.). Mugger have been released in the Manas river. There is, however, no information on the fate of these animals (Dorji, 1997 and unpubl. data). Extensive surveys are suggested for the Bado, Manas, Sunkosh Torsa, Raidak and the Puna Tsongchu river systems, from where there are sporadic reports of both mugger and gharial.

SALTWATER CROCODILE

The saltwater crocodile *Crocodylus porosus* (Plate 2, Fig. 3) is happiest in undisturbed mangroves, now one of India's most threatened habitats. It is no surprise that the 'saltie' is now a rare reptile in South Asia, and in India restricted to the Bhitarkanika Sanctuary in Orissa, the Sunderbans in West Bengal and the Andaman and Nicobar Islands, although historically this species occurred all along the west and southeast coast of India (Fig. 3). Table 3 gives the numbers of wild salties in India.

Orissa: In 1976-77, prior to releases, the density of salties in the Bhitarkanika Sanctuary was 0.87 individuals per km of river (excluding hatchlings), there were 29 adults, six subadults and 61 juveniles (Kar and Patnaik 1999). Following this, about 2,000 young crocodiles were released in Bhitarkanika over the next 24 years. Along with the successful restocking of gharial on the Chambal river, the Bhitarkanika saltie project was a dramatic success. In 1998, a total of 672 crocs were counted (including 150 hatchlings, 146 yearlings, 160 juveniles, 144 subadults and 72 adults) for a density of 5.0 crocs per km (Kar and Patnaik 1999). In 2001, a census conducted by the Rajnagar Mangrove and Forest Division came up with a figure of 1,285 salties in Bhitarkanika Sanctuary (Kalpavriksh 2002). The carrying capacity of the Sanctuary is limited by the absence of any buffer zone surrounding it. Any croc straying out of the protected area has little hope of survival. The rearing centre at Dangmal in the heart of the Sanctuary now has about 300 captive salties. Egg collection from wild nests has been stopped there.

West Bengal: The Sunderbans in West Bengal is a vast tidal swamp Tiger Reserve and part of one of the world's largest mangrove ecosystems. The sad part is that there are very few salties in what is ideal habitat for the species. The Bhagabatpur croc project of the West Bengal Forest Department has released 332 young salties in the 1.2-1.5 m size class in the Sunderbans since 1979, but there has been no monitoring or recent census (Chowdhary and Choudhury 1999). A lot of the best nesting habitat (swampy areas where freshwater meets the tidal zone) has been converted to paddy cultivation long ago. The entry of thousands of permit holders into the Reserve to fish, and to collect honey and leaves for roofing creates continuous disturbance.

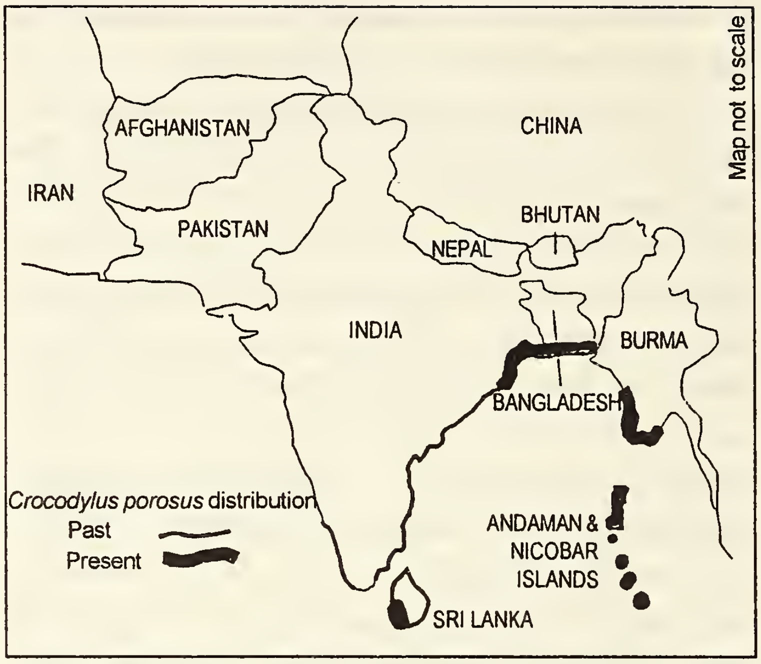

Fig. 3: Historical range and current distribution of the saltwater crocodile around the Indian subcontinent

Andaman and Nicobar Islands: In the Andaman and Nicobar Islands, the mangroves are still largely intact on the seaward side, but the inland portions of North Andaman Island were destroyed for firewood, and saltie nesting habitats used for growing rice (Whitaker and Whitaker 1978, Andrews and Whitaker 1994). Early

Table 3: Total wild saltwater crocodiles

Location	Estimated numbers released	Estimated wild salties
Orissa (Bhitarkanika Sanctuary)	2,000	672 (based on surveys)
West Bengal	332	200? (no recent data)
Andaman Islands	18	196 adults (based on surveys)
Nicobar Islands	Nil	100? (no recent data)
Total	2,350	1,168 +/- 300

Source: ENVIS (Wildlife & Protected Areas), Vol. 2, No. 1, 1999.

estimates of the population in North Andaman were 100-200 animals (Whitaker and Whitaker 1978). Choudhury and Bustard (1979) and Choudhury (1980) estimated that there were 50 breeding females for North Andaman Island. Andrews and Whitaker (1994) recorded the adult population of North Andaman as 95 animals, but a subsequent survey of a single island, Landfall, by Andrews (1999a) turned up 38 adults. Ten nests were located but North Andaman settlers had raided all. There are an estimated 19 adults in Middle Andaman, 19 adults in South Andaman and 27 adults in Little Andaman Island. The total estimate for adults in the Andaman Islands is thus 198 (Andrews 1999a).

Surveys conducted during 2000-2001 in the Nicobar Islands indicate that most of the adults and subadults have been taken by Thai poachers, except in the Galathea creek on the southeast of Great Nicobar island where a stable population still exists. The west coasts of Great Nicobar and Little Nicobar Islands have pristine habitats but population densities comprise very few adults and mostly hatchlings, yearlings, juveniles and a few subadults (Andrews, in prep.). A small population, of all size classes, occurs in the Middle Nicobar group, however the mangrove habitat in this region is very scanty and cannot sustain a large population.

Saltwater crocodiles outside India

Myanmar still has some very small populations and individual *Crocodylus porosus* scattered around the region. Surveys conducted by Thorbjarnarson *et al.* (1999) and Platt (2000) indicate that there are still small, fragmented populations and there is reproduction. Thorbjarnarson *et al.* (1999) reported 10 adults and 100 juveniles plus hatchlings and nests within the Meinmahia Kyun Wildlife Sanctuary, a 136 sq. km island. Outside the protected area, salties are near extinct, with only a few isolated individuals remaining.

Sri Lanka also has isolated populations of *C. porosus*, mainly on the southwest coast which still has some suitable habitat left. Detailed surveys are required to establish the status and survival potential of this, now rare, species.

The Madras Crocodile Bank Trust

The Madras Crocodile Bank was set up in 1975, for the breeding and rearing of South Asia's three crocodilians, for restocking wild habitats. It is also a research and public education centre. The Bank has achieved these goals with the breeding of thousands of mugger and also gharial and saltwater crocodiles. Close to a thousand crocs, besides eggs, have been supplied for restocking and for breeding programmes throughout India and in Bangladesh. The Bank has generated a number of documentary films, several books and over 600 scientific and popular articles. Over the past quarter century, more than 8 million people have visited the Bank and learned about crocodilians. The Crocodile Bank presently houses over 2,500 crocs of 14 species, snakes, lizards and turtles and is recognised as India's Centre for Herpetology. It is also the office of the Vice-Chairman, West Asia, Crocodile Specialist Group (CSG) of the IUCN Species Survival Commission (SSC). Current ongoing studies include crocodile surveys and habitat assessment, temperature sex determination, growth, behavioral, breeding biology and hormonal research.

DISCUSSION

Up to the 1970s, the three crocodilians of South Asia were in big trouble, due to killing for skins and meat, eating of their eggs and the loss of most of their habitat. In India the GOI/FAO/UNDP Crocodile Conservation Project, the Madras Crocodile Bank Trust, State Forest Departments, and like-minded individuals reversed the decline. About 9,800 gharial, mugger and saltwater crocodiles were released into established as well as newly protected areas in India, and for the first time positive publicity was given to these long feared and maligned reptiles. Data is difficult to extrapolate from the hodgepodge of non-standardised survey reports from some states and no data at all from others. However, it appears that there is little room for complacency with less than 1,500 wild gharial, 2,500 wild mugger and under 1,200 wild saltwater crocs left in India. There was a certain amount of spin-off from the Indian efforts in Nepal, where the Frankfurt Zoo helped start an egg collection, rear and release programme with advice from the FAO project. A similar start was made in Bhutan. Unfortunately Pakistan, Bhutan, Myanmar, Sri Lanka and Bangladesh have made no substantial conservation effort towards protecting the crocs they had left in the wild.

ACTION PLAN

In India, the IUCN/SSC/CSG Western Asia convened a regional meeting at the Madras Crocodile Bank Trust in 1993 (CSG-India 1993), and in Gwalior, Madhya Pradesh in 1997 (CSG-India 1997) resulting in an Action Plan. Similarly, the three crocodilians are given a place in the South Asian Amphibian and Reptile Specialist Group Action Plan.

Executive summary of the IUCN/SSC/Crocodile Specialist Group Western Asia region - Crocodilian Action Plan

1. Liaison with the Ministry of Environment and Forests, mainly to reconstitute the Technical Committee for crocodile conservation.
2. Research: The action plan identified several priority areas, including a database for wild and captive crocs, management and use. Main research priorities, however, will be continued surveys, monitoring, and identifying potential restocking sites.
3. Publicity and awareness, especially in areas of potential croc - human conflict.
4. Skill development and training.
5. Regional interaction and coordination.
6. Funding.

The outcome of these meetings has been circulated to the Government of India, all State Forest Departments, all regional members, IUCN/SSG/CSG Chairmen and Steering Committee Members.

THE FUTURE OF INDIA'S CROCODILIANS

After such an ambitious and successful beginning to the rehabilitation of India's three endangered crocodilians, it is very disappointing that few of the states involved have sustained some level of interest and action.

Currently there is very little monitoring, management or conservation efforts and studies on crocodiles within India and in the region, and there is an urgent need to revive this interest. It is also vitally important to implement a feasibility study for farming and ranching.

Crocodile conservation becomes necessary because, aside from the obvious value of the skin, meat and other by-products, the crocodile plays a vital ecological role as a master predator in the aquatic habitat where it lives. By preying on weak and diseased fish and animals, it maintains genetic quality; by its habit of selective feeding, it controls predatory fish. Its presence thus actually helps to increase yields of edible fish for man.

While many developing countries have found to their dismay that crocodile populations are remarkably easy to exterminate, crocodiles have responded well to protective management initiative, wherever adopted. Crocodile (and alligator) ranching, farming and rehabilitation programmes have been underway in several countries for a number of years. Most of these have been successful in maintaining wild crocodile populations and protecting millions of acres of wetland habitat, besides generating income for local people.

The programmes vary from country to country in dramatically different scenarios, from outright licensed hunting of adult alligators (as in Louisiana), to closed cycle captive breeding

(South Africa) and collection of eggs in the wild (Australia and Zimbabwe). Two things are common to all of these wildlife management operations: (a) local people (often tribal people) are making a good economic return, and (b) wild crocodile populations are doing well.

The Indian experience in crocodile conservation and rehabilitation in the last 25 years has been very encouraging. However, persisting with a simplistic policy of bans and attempts to preserve wildlife for its own sake, has again put crocodiles in the region under grave threat. Here, conservation is anti-people and the alarming decline in all our major wildlife species is the tragic result. No single conservation strategy can solve the problems faced by wildlife in India and it is vital that we continue to test new and innovative conservation methods — even if it means upsetting some people. Most opponents of sustainable use of wildlife are more interested in protecting the principle of "preservation" rather than trying to solve our problems of dwindling wildlife. Fundamentalist belief in the animal welfare movement and lethargy on the part of some key government bureaucrats are two reasons why conservation cannot achieve in India what so many other countries have accomplished.

In many countries, conservation through sustainable use is a strategy that has proved remarkably effective in saving wildlife and involving the people in it. It is essential that India too looks at all the various conservation options, including sustainable use of wildlife if we are to effectively conserve crocodiles and their dwindling habitat. Crocodile farming has done wonders for the crocodilians in many developing countries and India is lagging way behind.

Most captive crocodiles in India are now several generations removed from the wild (Plate 2, Fig. 4). They are no longer wildlife, they are domestic reptiles in the same way chickens, sheep, cows and pigs were once wild and have been domesticated by humans. Wildlife utilisation is already being practised on a massive scale by India's fishermen, tribals who collect minor forest produce and by the Irula Snake Catchers' Cooperative, whose members catch snakes to produce life saving antivenin. Crocodile farming can now point the way to a new and dynamic approach to managing wildlife — before we have lost everything.

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GROWTH OF KNOWLEDGE ON THE REPTILES OF INDIA, WITH AN INTRODUCTION TO SYSTEMATICS, TAXONOMY AND NOMENCLATURE

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Key words: Reptiles, taxonomy, systematics, history of herpetology, India, Fauna of British India

The progress in our understanding of the contents of the reptile fauna of India is reviewed. The early classification of the fauna was undertaken during Vedic times, and included groupings based on form, medium occupied, sensory powers and whether wild or domesticated. The Linnean system of binomial nomenclature, adopted since 1758, is the most widely used scheme of classification, but has its limitations, chiefly in being incompatible with the principle of common descent. Phylogenetic and other classifications, based on natural groups, have lead to a proliferation of studies on systematics, from the traditional studies of morphology and anatomy, to the use of more modern molecular techniques. Aspects of systematics, taxonomy and nomenclature are discussed for non-systematists. The last stocktaking of the reptile fauna of India, in the three volume Fauna of British India series by Malcolm Smith is compared with the fauna now known from the country. A general conclusion reached is that there is much to be learnt of the country's highly diverse and endemic reptile fauna, but efforts need to be accelerated in the face of loss of habitats as a result of deforestation and of systematic expertise itself, with cuts in research funding and realignment of policies on basic research.

INTRODUCTION

> "*Cross-cultural evidence indicates that people everywhere spontaneously organize living kinds into rigidly ranked taxonomic types despite wide morphological variation among those exemplars presumed to have the nature of their type.*"
>
> (S. Atran, 1990: 70)

The earliest known attempt to classify the reptiles of India was made during the Vedic period, based on form, reproductive mode, medium occupied (earth, air or water), the presumed number of sensory powers possessed, and whether wild or domesticated (Rao 1957, Ghildial-Sharma and Sharma 1989). For instance, the work 'Manu Smriti', compiled between 200 BC and 200 AD, classified animals on the basis of their reproductive modes, and snakes, crocodiles and tortoises, therefore, were grouped along with birds and fish, for being (primarily) oviparous. The UMASVATI, a Jain work written between 135-219 AD, classified animals according to their sensory powers. Within this system, reptiles were grouped with humans, for possessing the senses of sight, hearing, taste, smell and touch. The classification systems of ancient Indian physicians, Charak and Susruta, made use of differences based on habitats, and the eight categories identified include aquatic species that live in water, those in dry hills, amphibious species and animals living in marshy or water-logged areas. The work SUSRUTA NAGARJUNA classified snakes into 5 groups (including both venomous and non-venomous).

So why did our ancestors consider it important to classify animals? There are two fundamentally opposing schools of thought. Diamond (1966) and Gould (1979) considered the primary purpose of indigenous names to be utilitarian. On the other hand, the complex classification and naming process (= folk taxonomy and nomenclature) support Berlin's (1992) theory that humans are innately curious about the natural world, and that names are supplied to species that may not always have a direct utilitarian value.

In taxonomy, the modern science of classification of animals and plants, it is said that stability of combinations of nomen is an indication of lack of progress! This generalisation is true for

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the herpetofauna of India and surrounding countries for the latter half of the last century, when workers had to depend on the three-volume (1931-43) monographic review of the herpetofauna of southern and parts of southeast Asia by Malcolm Arthur Smith. These volumes, which are understandably dated, did not cover the amphibians, despite giving their titles, though this group was covered in its entirety in an even earlier work, that of Boulenger (1890). This essay briefly summarises the history and direction of the modern science(s) of systematics and taxonomy, and thereafter reviews the status of taxonomy, systematics and nomenclature of reptiles inhabiting the Republic of India. It also analyses changes in the current understanding of the group compared with that which existed at the time of Malcolm Smith's monographs. The essay concludes with comments on the future of systematic research in the country. A glossary of technical terms used in systematics, taxonomy, nomenclature and in biogeography is appended.

LINNEAN CLASSIFICATION

> "*For his descriptions of living nature Linnaeus drew on his daily readings in Roman poetry, particularly Ovid and Virgil.... Read through the prism of later Romantic nature poetry, Linnaeus' nature writings are beautiful.*"
>
> (L. Koerner, 1990: 23)

Classification is defined as the grouping of objects that share properties/attributes into classes, although contemporary practise of systematics and taxonomy places emphasis on common ancestry, rather than commonality of character states (see 'Phylogenetic classification').

The system of binomial nomenclature owes its existence to the Swedish physician, Carolus Linnaeus or Carl von Linné (1707-78). Linnaeus arranged all species of plants and animals known to him in a hierarchical scheme, arranging species within a genus, and genera within a family, and families within a class. Nearly two million scientific names have been proposed for animal taxa since 1758 (Hammond 1992). Many were named in the last century, and most of these currently refer to taxa valid at present. Some are no longer in use, as they were subsequently shown to be a less recent name of an existing taxa (= junior synonyms) or same name for a different species (= homonym). More rarely, a name is not available because it has been suppressed by the International Commission of Zoological Nomenclature, for the purpose of achieving stability in names. However, names placed in synonymy do not disappear from use, they are listed as such and especially when groups are revised, some of these may be revived to accommodate distinct populations warranting a distinct taxonomic status, especially from within a constellation of closely related species.

To become available for any nomenclatural act in zoology, nomina (namely, names of taxa with a nomenclatural status) need to have several properties. They must be published intentionally as new, following the binomial system of nomenclature, as outlined in the Fourth Edition of the International Code of Zoological Nomenclature (International Commission of Zoological Nomenclature 1999). The earliest nomina available are those mentioned in the 10th edition of Linnaeus's SYSTEMA NATURAE (published in 1758), which was taken as the starting point for biological names. New names being proposed are to be followed by the words 'new species' or 'sp. nov.'; in the past, the word(s) or letters 'Mihi' or 'M' (meaning 'from me' or 'to me'), 'Nobis', 'Nob.' or 'N' ('from us' or 'to us') were used to indicate that a new name was being proposed. However, in older works, these were also used to designate new name combinations and spellings.

A few words about the origin and evolution of modern concepts of systematics and taxonomy may be in order. Contemporary classification of the living world is based on the Darwinian theory of evolution (or more accurately, the premise of common descent), and uses the Linnean system of binomial nomenclature (after January 1, 1758), a 'downward' classification system. Hierarchies of the Linnean system, therefore, do not necessarily reflect natural (that is, geneological) relationships as understood at present (see Stevens 1997).

Categories in the Linnean system include: kingdom, phylum, class, order, family, genus (plural: genera), and species (singular and plural), and are used to convey information on relative positions of taxa in the taxonomic hierarchy. Standardised termination (suffix) of name indicates a specific category:

–ini is a Tribe name (e.g. Ranini, to which the common frogs belong)

-inae is a Subfamily name (e.g. Lygosominae, to which the slender-bodied scincid lizards belong)

–idae is a Family name (e.g. Varanidae, the family including monitor lizards and Bataguridae, the family to which hardshelled turtles of Asia are assigned)

–oidea is a Superfamily name (e.g. Gekkonoidea, to which gekkonids and eublepharids belong)

Scientific names of organisms are typically coined in ancient Greek or perhaps more commonly, in Latin, a language no longer in use (and therefore not subject to change, as those that are in use are). Latin and Greek were the languages of learned people, such as scientists and other scholars. Scientific names of organisms can also be derived from indigenous names, such as the nomen for the crocodilian *Gavialis* Oppel, 1811, derived from the north Indian vernacular name, for this sole living member of the Family, 'Gharial' (from ghara, meaning earthen-pot-like), an allusion to the narial excrescence in adult males. The 'r' was apparently misspelt 'v' in the original description.

PHYLOGENETIC CLASSIFICATION

"The conventional Linnaean hierarchy will not be able to survive alone: it will have to coexist with the ideas and terminology of phylogenetic (cladistic) systematics...

...One should always keep in mind that an important function of classifications is information retrieval."

(Preface by A. Minelli & O. Kraus to the International Code of Zoological Nomenclature, Fourth Edition, 1999: XVII)

The number of species concepts in theory and practice continues to proliferate. The infertility criteria has been traditionally used as a marker for species limit in the Biological Species Concept, that defines species as reproductively isolated groups of interbreeding organisms, as opposed to the Recognition Species Concept (most inclusive population of individual biparental organisms which share a common fertilisation system) or the Phylogenetic Species Concept (clusters of organisms possessing uniquely shared characters). See also the section 'Species Concepts' for definitions of these and other concepts.

Some shortcomings of the Linnean system:

- Sometimes, the Linnean system is thought unnecessary for phylogenetic taxonomy;
- There is no information on common ancestry;
- The categories themselves are insufficient to specify relationships.

These problems make the adoption of the phylogenetic system of classification more attractive.

Emil Hans Willi Hennig (1913-76), in the mid-1900s, presented a system of classification based on phylogeny, underlining common descent as a criterion for relatedness and excludes reliance on mere similarity. Originally published in German in 1950 and translated into English in 1966, it argues that biological classification should be guided by the evolutionary theory ["The best general classification is one that exactly reflects the geneological (or phylogenetic) relationships"]. A phylogenetic tree constructed shows a branching diagram of entities with hypothesised genealogical relationships and sequence of historical events.

The states for a particular character are identified in each ingroup and outgroup, the states polarised to distinguish ancestral (plesiomorphic) and derived (apomorphic) states, and the shared, derived (synapomorphic) states plotted onto the cladogram of the ingroup. The tree thus constructed shows the historical pathway followed within the ingroup in the evolution of a certain character. Modern phylogenetic systematics (also referred to as 'cladistics') therefore dates from the work of Hennig. Among the anomalies in the old vs. new systems of classification is the discovery that some groups (including Reptilia) are paraphyletic (i.e., their members do not share a common ancestor). The squamates form a natural group, lizards and snakes sharing sister relationships, and crocodilians are in fact closer to birds than to other living reptiles, and turtles are not related to either of these three groups, and have a somewhat unresolved relationship (see for instance, Rowe 1986). Thus, 'Reptilia' as a clade is an unnatural entity and comparisons made on their biology that exclude other groups, especially birds, are, at best, incomplete. Indeed, these findings challenge the naturalness of the group of organisms dealt with in the science of herpetology, a group that includes the amphibians (of uncertain relationships, although the group itself appears monophyletic; Zardoya and Meyer 2001). Nonetheless, two textbooks of herpetology have appeared in recent years (Pough *et al.* 1998, Zug *et al.* 2001), and there is a general proliferation of societies, journals and symposia dedicated to the science of herpetology.

Phylogenies provide important insights into taxonomy, including the evolution of characters and long-term patterns and dynamics of adaptation and divergence. The three overlapping charges of modern systematics include:

- The naming of species, according to the rules of nomenclature
- Their classification, and
- The reconstruction of phylogenies.

Thus, the purpose of classification of organisms has witnessed a shift away from the mere groupings of species at the time of Linnaeus, to the arrangement of taxa to show natural (or evolutionary) relationships. Recent advances in molecular techniques provide new characters for refining classification, that are particularly useful for recognition of cryptic species, recognition of large, unresolved groups and for resolving phylogenies at higher levels.

Despite its widespread acceptance for the past two and a half centuries, the Linnaean binomial nomenclature is now known to be logically incompatible with the phylogenetic nomenclature (*sensu* de Queiroz and Gauthier 1992). The concept of genus, in particular, while mandatory for binomial nomenclature, cannot be incorporated into a phylogenetic system of nomenclature, which requires abandonment of mandatory ranks. While no resolution to nomenclature under the system is at hand yet, Cantino *et al.* (1999) presented as many as 13 methods for naming species in the context of phylogenetic nomenclature. The systems take into account the stability, uniqueness and ease of pronunciation of species nomens; their capacity to convey phylogenetic information, and distinguish nomen governed by a Code of Phylogenetic Nomenclature (now under preparation) both from clade nomens and from species nomens governed by the current Codes of Botanical or Zoological Nomenclature.

SPECIES CONCEPTS

"*In the consideration of competing species concepts it is necessary that systematists examine the precise implications of each, in terms of theory as well as practice.*"

(J.I. Davies, 1995: 556)

"*In the field of nomenclature there is a set of rules to guide us, but when it comes to species concepts, it is 'everyone for himself'...*"

(J.W. Arntzen & A.M. Bauer, 1996: 321)

Malcolm Smith's tomes, upon which the contemporary classification of Indian reptiles (see Table 1) is largely based, follows the typological species concept. Type specimens are designated as an objective and non-ambiguous reference to a natural population of a specific taxa (Dubois and Ohler 1996). The type locality refers to the geographic area from where the sample was extracted. A single specimen that forms the basis for the description of a new species is referred to as 'holotype'. A series of specimens form syntypes ('cotypes' in the older literature). From the syntype series, a subsequent author (such as a reviser) can designate a lectotype, which becomes the nomen-bearing type. As a result, the rest of the syntypes become paralectotypes, and lose their primary type status. If types from the original description are lost, destroyed or otherwise not available for study, a neotype can be designated to bring stability to the group. Ideally, a neotype is obtained from the type locality or a locality close to it. Typological thinking of essentialism, which dates back to Aristotle, is non-evolutionary in nature, and one might therefore argue for the abandonment for such a non-evolutionary scheme of classification. Particularly, one of several lineage-based species concepts may be more appropriate, as these are consistent with the evolutionary history.

We assume here that species are real entities and not concepts for the purpose of understanding the natural world (see Hull 1976, for a discussion). Species concepts abound. Opposing camps offer the following (for more comprehensive reviews, see Ereshefsky 1992, Lee 1995):

The Biological Species Concept is associated with the idea that species are populations of interbreeding organisms, that are reproductively isolated from other such groups (see Mayr 1942, 1963).

The Evolutionary Species Concept emphasises the extension of species through time, defining species as a lineage of ancestral-descendant sequence of populations that evolve separate from other such lineages, with its own unitary evolutionary role and tendencies (Simpson 1961, Wiley 1978). Frost and Hillis (1990) discussed the application of the Evolutionary Species Concept to herpetofaunal groups.

In the Recognition Species Concept, species definitions are associated with the 'recognition concept' emphasising the unification of species rather than their separation from one another. It emphasises common fertilisation and specific mate-recognition systems shared by conspecifics, rather than reproductive isolation between heterospecific organisms (Patterson 1980, 1985).

The Isolation Species Concept, an alternative to the Recognition Species Concept, emphasise reproductive isolation between organisms (Patterson 1985, Dobzhansky 1970).

The Ecological Species Concept, a modification of the Evolutionary Species Concept, emphasises the importance of ecologically based natural selection in maintaining species, which defines species as a lineage or a closely-related set of lineages that occupies an adaptive zone minimally different from that of any other lineage in its range and which evolves separately from all lineages outside its range (Van Valen 1976).

In the Phenotypic/Phenetic Species Concept, species definitions that emphasise the evidence and operations used to recognise species in taxonomic practice, especially those within phenetic or numerical taxonomy, and perceive species as discrete clusters of morphologically similar organisms, isolated from other such clusters (Sokal and Crovello 1970).

The Phylogenetic Species Concept, associated with phylogenetics or cladistics, is used for four classes of species definitions (Davies 1995). The Hennigian Species Concept recognises species as lineages that occupy the internodes of a phylogeny and go extinct when a speciation event takes place. The Autapomorphic (or Monophyletic) Species Concept recognises species as minimal monophyletic groupings, as evidenced by autapomorphies. The Phylogenetic Species Concept recognises species as divergent population systems (with fixed or diagnostic characters combinations that need not be autapomorphic). Finally, the Geneological Species Concept is similar to the Autapomorphic Species Concept but replaces the emphasis on monophyly of organisms with monophyly of genes carried by organisms.

The General Lineage Concept of de Queiroz (1998) concludes, after reviewing the various species concepts, that these refer to all aspects or properties of a single common entity, and that differences between these definitions are not as disparate as it would appear (see also de Queiroz 1999).

Adoption of either Simpson's (1961) Evolutionary Species Concept or de Queiroz's (1998) General Lineage Concept, for instance, has led to dramatically altered faunal lists for Continental North America (Collins 1990), México (Grismer 1999) and the Philippines Archipelago (Brown and Diesmos 2001). As might be expected, difficulties in standardising lists (for biotic inventories and for a variety of other needs), as a result of proliferation of checklists based on different species concepts, exist not just for reptiles, but also for well-studied groups such as birds (see Helbig *et al.* 2002, McKitrick and Zink 1988).

THE CODE OF ZOOLOGICAL NOMENCLATURE

"*Ordinary languages grow spontaneously in innumerable directions; but biological nomenclature has to be an exact tool that will convey a precise meaning for persons in all generations.*"

(Preface by J.C. Bradley to the International Code of Zoological Nomenclature, First Edition, 1961)

The word 'nomenclature' is derived from the Latin *nomen* (= name) + *calare* (= to call), and the function of scientific nomenclature is to facilitate communication between biologists (who may speak different languages). In this essay, 'nomen' refers to scientific names, especially those coined according to the rules of binomial nomenclature. Scientific nomen are typically coined in Latin (a dead language) or ancient Greek. Article 36 of the Code of Botanical Nomenclature even makes it mandatory to provide descriptions or diagnoses of new species in Latin, although zoologists have been exempted from this practice. Nonetheless, the technical vocabulary of practising systematists rests on an extensive glossary of Latin, derived largely from the early works of Pliny the Elder (23-79 AD), with significant Greek influence (Stearns 1992).

The International Code of Zoological Nomenclature (ICZN) is the law-book for zoological systematists, and applies to both living and fossil animals (botanists and bacteriologists have their own Code of Nomenclature). It is based on, and defines the Linnean nomenclatural system of classification (ranks of taxa). The Code of Zoological Nomenclature appeared in 1886, and early authors are therefore sometimes inconsistent in their nomenclatoral practices. The current version is the Fourth Edition of 1999, which came into force from January 1, 2000, and replaces the Third Edition of 1985, and takes into account over 500 written comments by zoologists and groups of zoologists, made in response to a Discussion Draft that was distributed widely in 1995.

The Code adopted by the International Union of Biological Sciences, is in dual English-French texts, and published by the International Trust for Zoological Nomenclature, London. The publication comprises 90 Articles, a Glossary and two Appendices (Code of Ethics and General Recommendations). In its own words, the Code "provides the maximum universality and continuity in the scientific names of animals compatible with the freedom of scientists to classify all animals according to taxonomic judgement."

Some properties of scientific nomen include:

- uniqueness (no two species should have the same nomen),
- universality (one nomen applied to the same species worldwide), and
- stability (in case of old, unused nomen threatening relatively recent well-used nomen, the Commission has the powers to set aside the former).

The binomial system of nomenclature prescribes how nomen are to be written: every species has a generic nomen and specific nomen (e.g. *Homo sapiens*, for humans), and both generic and specific nomen are in italics. Subspecies nomen are also rendered in italics, but not categories above the genera, such as Family and Order nomen. ICZN makes it compulsory for nomen not to be hyphenated (e.g. *novae-guineae*) and special font types representing diacritic marks (e.g. accent, cedilla, tilde and umlat) are not permitted. The name of authority and year follow the scientific nomen (species/subspecies nomen) of taxon, without parentheses in case an original name suggested at the time of description is valid. If the species nomen has been allocated to a genus different from the one it was originally allocated to, the name(s) of author(s) are placed in parentheses. An invalid nomen (such as a junior synonym) may be written without the use of parentheses. Finally, nomen are available for use only if they are validly published (in journals, monographs, books and Faunas). Publication of new nomen in electronic media, meeting notices and conference abstracts do not constitute a formal publication from a nomenclatural standpoint. As for the nomen itself, every author is entitled to provide a nomen for a valid taxon, regardless of how long, unpronounceable, or grammatically incorrect it might be. Exceptions where the International Commission of Zoological Nomenclature have intervened are rare, and include the case of Dybowski's (1926) rather lengthy nomen such as *Siemieniewicziechinogammarus*, *Axelboeckiakytodermogammarus*, *Garjajewiakytodermogammarus* and *Cancelloidokytodermogammarus*, which were suppressed (Opinion 105, International Commission of Zoological Nomenclature 1929). Nomina with the potential to offend or hurt a community can also be suppressed.

Estimates of global species richness of animals varies between 5-15 million, of which slightly over a million species bear a scientific nomen (Erwin 1997, Stork and Gaston 1990). The geographical trend in the distribution of species is higher species richness in tropical, rather than temperate regions and high richness values for such environments as rainforests and coral reefs. Nonetheless, many species nomen are synonyms (duplicate names for the same biological species) or nomina dubia (names without reference to a biological species), making estimates of total species counts difficult (Alroy 2002). The most current inventory of the world's described species can be found at http://www.sp2000.org.

OLD TECHNIQUES AND NEW

"*The development of time-shared, multi-access computing systems utilising standard teletype machines and the availability of extremely simple programming languages are recent events that provide an opportunity for some major changes in the work of systematists.*"

(J.A. Peters, 1969)

"*In the 1950s, it was cyto-taxonomy...Counting chromosomes and analysing karyotypes was the 'in-thing', claiming to solve all taxonomic problems. Nearly concurrent with fun with numbers, was experimental taxonomy: determining species relationships by testing infertilities via hybridisation...*

Then in the mid-1960s another fad dominated the systematics scene — numerical taxonomy...The next holy grail was the fertile family of flavonoid compounds that took the spotlight during the era of chemotaxonomy. Note *that each of these fads faded, if not to oblivion, at least to second class citizenship...*

And so now in the midst of the molecular taxonomy craze, I must ask: How long will it last? What is the life expectancy for this fun with isozymes and nucleic acids for the taxonomist? If the current preoccupation is anything like its predecessors, it will be replaced. By what? I predict that the next 'in thing' will be to determine the genetic basis of character differences."

(A.R. Kruckeberg, 1997)

Classifications of organisms have been traditionally based on morphology and anatomy, that is, structures that can be perceived by the naked human eye or through optical instruments (such as microscopes). Recent advances in physics and chemistry make it possible to utilise techniques that were unthinkable a few decades ago. These include bioacoustics (as it increasingly becomes evident how species-specific animal calls are, because of their connection with reproductive activity), and especially bio-chemical techniques, including protein electrophoresis.

Molecular systematics makes use of proteins and genes, in drawing systematic and biogeographic conclusions, including nuclear DNA (deoxyribonucleic acid), mitochondrial DNA and ribosomal nucleic acids (the basic assumption is that hereditary information is carried by molecules of DNA). Recent advances in molecular techniques provide new characters for refining classification. A variety of molecular techniques are available, including allozyme/isozyme analyses (comparisons in net electric charge); mitochondrial DNA (mtDNA, which is useful in reconstructing phylogenetic history), through PCR amplification and sequencing (allowing rapid amplification of sequences from a large number of samples). Phylogenetic reconstruction in molecular systematics is commonly done using mitochondrial gene sequences and less commonly, sequences of nuclear ribosomal RNA genes (see reviews in Hillis *et al.* 1996).

Molecular techniques are also crucial for studies in phylogeography, described as "the field of study concerned with the principles and processes governing the geographical distribution of geneological lineages, especially those within and among closely-related species" (Avise 2000). Phylogeography is a subdiscipline of biogeography that seeks to interpret how historical processes have affected geographical distributions of gene-based organismal traits. Genetics provide answers to questions regarding measures of migration (gene flow) between populations and separating human-induced factors from natural cyclicity of population contraction and expansion. Two types of conservation units may be discernable, using tools in molecular phylogenies: management units (MUs), which represent sets of populations that are currently demographically independent and evolutionarily significant units (ESUs) that together encompass the evolutionary diversity of a taxon (Moritz 1996). Both are significant, the former for short-term management, the latter for long-term issues.

An archive of biological data and software to promote public access to freely available information can be found at http://www.iubio.bio.indiana.edu.

WHY SYSTEMATICS?

"*Among many others, butchers and artists, farmers and showmen all deployed distinctive taxonomies in their work...* "

(H. Ritvo, 1997: xii)

"*For several of us, the priority is to document biodiversity and to provide identification tools: both are needed to promote awareness and conservation. This means goodbye to time-consuming, low output methods. Methods have to be selected, case by case, according to the material being investigated, the threats facing a habitat, the urgency of the* *threats, the needed output, cost efficiency and context. In the real (non-academic) world, this is just called efficiency!*"

(M. Kottelat, 1995)

Although systematic biology has been known to be inextricably linked to conservation biology, and indeed to human welfare itself, the principles of systematics have not entirely been integrated into the principles and practice of conservation science (Dimmick *et al.* 1999). For instance, classification and naming of organisms, especially endangered species, is the first step towards their recognition, and subsequently, their conservation and management. Poor knowledge of systematics and taxonomy have been considered responsible for the inability to recognise severe threats to the survival of many species of European freshwater fishes, a group under study for over 450 years (Kottelat 1997) and even for extinction of taxa (Daugherty *et al.* 1990). It is now generally acknowledged that many of the most important organisms in agriculture are little understood in the context of systematics, with serious implications for pest management and control, and sustainable agriculture (Miller and Rossman 1995). And it was systematists who drew global attention to the biodiversity crisis.

Systematic Agenda 2000, a global initiative to discover, describe and classify the world's species, is guided by a consortium of botanists and zoologists. It outlines a programme to discover, describe and inventory the Earth's biological diversity, seeks answers to four fundamental questions:

- What are the Earth's species?
- What are their properties?
- Where do they occur?
- How are they related?

Most of the world's systematists work through or with museums that have collections of preserved materials belonging to their particular group of specialisation. Natural history collections themselves have a variety of uses: apart from having aesthetic and cultural values, they have proved invaluable in documenting the distribution, variation and seasonality of activity of species (Earl of Cranbrook 1996), and supporting studies of time series to investigate changes in ecology (Brooke 2000) and declines of extant species (Shaffer *et al.* 1998).

Notwithstanding the fact that a large number of museums, regional and national, exhibit natural history objects, only a few of these are genuinely research museums, in that they can hardly be considered caretakers of systematic resources and support a staff dedicated to undertaking full time research. Among the more well-known ones in India are the Zoological Survey of India, headquartered in Kolkata, with regional stations throughout the country, and the Natural History Museum of the Bombay Natural History Society in Mumbai. Both institutions have collections that date back to the middle or early part of the 19th Century, including many herpetological types. The staff of both institutions have traditionally played an important role in promoting systematic zoology in the country and their influence in the region has been significant, particularly in view of the fact that few tropical Asian countries have natural history museums (see Ng 2001). A research museum is thus the caretaker of not only biological specimens presented in life-like dioramas for the visiting public, but also a repository for skins, moults, casts, skeletons, cleared-and-stained as well as whole specimens in fluids, and their tissues, as well as associated information, such as georeferenced localities and ecological data, for scientists. The databases can be made publicly available either in hardcopy (such as the museum's official journals or occasional publications), softcopy on CDs and diskettes or on the Web, such as México's 1,069 bird species, listed at http://chipotle.nhm.ukans.edu/nabin. A large database, Atta (after the genus of leaf-cutting ants from the New World) of the Instituto Nacional de Biodiversidad (INBio), a scientific institution, with 'social orientation' from Costa Rica, maintains a relational database comprising over 2 million records. Besides basic data, Atta also stores taxonomic information, photographs and illustrations, and is viewable at http://www.inbio.ac.cr/en/default.html.

Many of the species awaiting formal discovery by modern science in the future are predicted to be taxonomically cryptic, or similar to known species, hence simply not recognised until a thorough revision of the group is undertaken, sometimes utilising contemporary laboratory (including gene sequencing) and field (ecological and behavioural) techniques. Cryptic species are frequently localised, some restricted to patches of forests a few dozen hectares in extent or to one or two adjacent hill streams, making their discovery difficult, unless a concerted effort is made to conduct an exhaustive inventory. Other species may show populations with disjunctions, structured into well defined phylogenetic assemblages or metapopulations, some with significant genetic variants, all requiring careful consideration for identification and conservation (see Sites and Crandall 1997). Supplying names to these "hidden" species, thus, is the first step towards their universal recognition and protection (Longino 1993, Wheeler 1995). True, the recognition of cryptic species is increasing the conservation burden; it also emphasises the importance of moving away from taxon-based conservation to protection of the environment at the level of landscapes and ecosystems (Lovich and Gibbons 1997).

One of the goals of these studies is also to develop stable taxonomies of the fauna. A product for the public and often, for industry, as a result of these researches is comprehensive (i.e., covering all nominal taxa) monographs, revisions, field guides and other identification devices. Field guides are important in promoting conservation awareness and action and assisting capacity building. They are also resources supporting environmental assessments (such as monitoring and evaluation) of development projects, encouraging ecotourism, building biodiversity databases, land-use planning through GIS applications and the production of regional and international Red Data Books of Threatened Species (Whitten 1996).

COMPARISONS WITH SMITH'S *FAUNA*

> "*Systematic collecting has been carried out in nearly all parts of the Indian Empire, and, except in the more inaccessible mountain districts, the herpetological fauna of the country is now pretty well known.*"
>
> (M.A. Smith, 1931: 1)

Malcolm Smith's three volume Fauna of British India on 'Amphibia and Reptilia' (although the first group was not covered), published in 1931, 1935 and 1943, was a vastly revised edition of the 1890 volume bearing the same title by George Boulenger. The latter series was to set high standards for monographs that have been emulated by many others for different countries and regions of the world. Indeed, nearly half a century after the three volumes were published, they still remain the single most important source of information for practising reptile systematists and others who wish to obtain information on the region's reptile fauna. A large number of species have been described since the days of Malcolm Smith (who, incidentally, never conducted field work in India, but had material from Indian and other museums mailed to him in London), several species were omitted and a number have been synonymised under other species, or revived from synonymy. Several new genera have been created to house species known at the time of the Fauna, and a few have been relegated to the synonymy of existing genera. In this section of the essay, a comparison is made with the systematic knowledge of Indian reptiles at the time of Smith's Fauna and that which exists at present.

Table 1 presents a summary of species nomen of Indian reptiles that are considered valid. Column 1 lists the original nomen, retaining the original orthography; Column 2 lists the nomen as used in the Fauna of British India volumes; Column 3 provides the current nomen of the taxon; Column 4 provides the citation for the preceding nomen combination, if different from that in Column 3; and Column 5 provides additional nomenclatural remarks, as thought appropriate. Nomens of families, genera and species are arranged alphabetically, and not in any inferred evolutionary order. Finally, a glossary of technical terms is provided for non-systematists (Appendix 1). The cut-off date for the checklist was January 31,2003.

The geographical coverage of Smith's Fauna was southern, and perhaps because Smith was more familiar with the southeast Asian region, being the Physician to the Royal Court of Bangkok (see Smith 1957 for an account), extending to mainland southeast Asia, up to southern Thailand. Among species now known to occur within the political boundaries of the Republic of India, 450 species were listed in Smith. The current checklist counts 506 species. Species concept employed by Smith, different approaches, not to mention paucity of material, are factors which are partially responsible for differences in the allocation of species nomen in the two columns. For instance, Smith's (1943) volume on snakes recognised a single species of Indian *Naja*, even treating the Andamans endemic, *sagittifera* as a synonym of *N. kaouthia*. More recent studies by Wüster (1998a) and Wüster and Thorpe (1992) have shown that a specific status is more appropriate for these populations. More importantly, the typological classification employed by systematists at the time of M.A. Smith has the potential to misrepresent actual biodiversity values in terms of species richness. Included in the problem is the more frequent usage at the time of Smith of the subspecies category [frowned upon by proponents of the Evolutionary Species Concept (and other related concepts). However, the subspecies concept, synonymous with 'island races' (of Inger 1954, 1961) and pattern classes (e.g. Grismer *et al.* 1994, Shaffer and McKnight 1996), continues to have its proponents (see, for instance, Smith *et al.* 1997).

The two lists differ in other ways too. As many as 139 species are now assigned to genera different from that in Smith. The usage of names of species is made not only by systematists and taxonomists, but also by practising physiologists, geneticists, ecologists, conservationists, and policy makers, to name just a few end-users of taxonomic lists. Frequent name changes can be exasperating to many, some of whom perhaps unrealistically wish to have stability of names for a fauna that is poorly understood. However, as many as 308 species of Indian origin listed in Smith have been allocated to genera different from that originally described in, suggesting that we are on the path towards reaching a more natural system of classification, if the binomial system of nomenclature continues to survive. A number of species whose nomen were made available in older works were inexplicably unlisted in Smith's Fauna, even as synonyms, including *Asymblepharus tragbulensis* (Alcock, 1898), *Barkudia melanosticta* (Schneider, 1801), *Coluber vittacaudatus* Blyth, 1854 and *Typhlops exiguus* Jan in: Jan and Sordelli, 1864. It is possible that the present list too omits some valid species described in obscure works. Indeed, the non-availability of some publications has been a serious impediment to studies, and several critical works dealing with systematics and nomenclature of the region's reptiles are not easily accessible to biologists. These include unpublished theses (e.g. that of Moody 1980, which suggested the overhauling of the generic-level systematics of the Agamidae) and works in languages other than English, and frequently of limited circulation (that are far too numerous to mention in this essay).

Table 1: Synopsis of names of reptile species known from India. Nomenclature in M.A. Smith's *Fauna* compared with that followed at present. For original names, the original orthography has been retained (including upper case first letters for species nomen, accents, etc.)

Original name	Name in Smith's Fauna	Current name	References	Remarks
CROCODYLIDAE				
Crocodylus palustris Lesson, 1831	*Crocodylus palustris*	*Crocodylus palustris*	-	-
Crocodylus porosus Schneider, 1801	*Crocodylus porosus*	*Crocodylus porosus*	-	-
GAVIALIIDAE				
Lacerta gangetica Gmelin, 1879	*Gavialis gangeticus*	*Gavialis gangeticus*	-	-
BATAGURIDAE				
Emys baska Gray, 1830	*Batagur baska*	*Batagur baska*	-	-
Testudo amboinensis Daudin, 1801	*Cuora amboinensis*	*Cuora amboinensis*	-	-
Cyclemys oldhamii Gray, 1863	*Cyclemys dentata*	*Cyclemys oldhamii*	Fritz *et al.* (1996, 1997)	-
Emys Hamiltonii Gray, 1831	*Geoclemys hamiltoni*	*Geoclemys hamiltonii*	-	-
Geoemyda silvatica Henderson, 1912	*Geoemyda silvatica*	*Geoemyda silvatica*	-	-
Emys Thurjii Gray, 1831	*Hardella thurgi*	*Hardella thurjii*	-	-
Emys dhongoka Gray, 1832	*Kachuga dhongoka*	*Kachuga dhongoka*	-	-
Emys kachuga Gray, 1831	*Kachuga kachuga*	*Kachuga kachuga*	-	-
Geomyda tricarinata Blyth, "1855" 1856	*Geomyda tricarinata*	*Melanochelys tricarinata*	McDowell (1964)	-
Emys trijuga Schweigger, 1812	*Geoemyda trijuga*	*Melanochelys trijuga*	McDowell (1964)	-
Batagur (*Morenia*) *petersi* Anderson, "1878" 1879	*Morenia petersi*	*Morenia petersi*	-	-
Batagur smithii Gray, 1863	*Kachuga smithi*	*Pangshura smithii*	Das (2001); Iverson (in prep.); see also Moll (1987)	-
Kachuga Sylhetensis Jerdon, 1870	*Kachuga sylhetensis*	*Pangshura sylhetensis*	Das (2001); Iverson (in prep.); see also Moll (1987)	-

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Emys tectum Bell in: Gray, 1831	*Kachuga tectum*	*Pangshura tectum*	Das (2001); Iverson (in prep.); see also Moll (1987)	-
Emys tentoria Gray, 1834	*Kachuga tectum tentoria*	*Pangshura tentoria*	Das (2001); Iverson (in prep.); see also Moll (1987)	-
Cyclemys mouhotii Gray, 1862	*Cyclemys mouhoti*	*Pyxidea mouhotii*	McDowell (1964)	-
CHELONIIDAE				
Testudo Caretta	*Caretta caretta* Linnaeus, 1758	*Caretta caretta olivacea*	-	Smith's (1931: 71) concept was a composite of *Caretta caretta* and *Lepidochelys olivacea*
Testudo Mydas Linnaeus, 1758	*Chelonia mydas*	*Chelonia mydas*	-	-
Testudo imbricata Linnaeus, 1766	*Eretmochelys imbricata*	*Eretmochelys imbricata*	-	-
Chelonia olivacea Eschscholtz, 1829	*Caretta caretta olivacea*	*Lepidochelys olivacea*	-	Smith's (1931: 71) concept was a composite of *Caretta caretta* and *Lepidochelys olivacea*
DERMOCHELYIDAE				
Testudo coriacea Vandelli, 1761	*Dermochelys coriacea*	*Dermochelys coriacea*	-	-
TESTUDINIDAE				
Testudo elegans Schoepff, 1795	*Testudo elegans*	*Geochelone elegans*	Crumly (1982, 1984)	-
Testudo elongata Blyth, 1853	*Testudo elongata*	*Indotestudo elongata*	Crumly (1982, 1984)	-
Testudo travancorica Boulenger, 1907	*Testudo travancorica*	*Indotestudo travancorica*	Crumly (1982, 1984)	-
Testudo emys Schlegel & Müller in: Temminck, 1840	*Testudo emys*	*Manouria emys*	Crumly (1982, 1984); Obst (1983)	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
TRIONYCHIDAE				
Testudo cartilaginea Boddaert, 1770	*Trionyx cartilagineus*	*Amyda cartilaginea*	Meylan (1987)	-
Trionyx gangeticus Cuvier, 1825	*Trionyx gangeticus*	*Aspideretes gangeticus*	Meylan (1987)	-
Trionyx Hurum Gray, 1831	*Trionyx hurum*	*Aspideretes hurum*	Meylan (1987)	-
Trionyx Leithii Gray, 1872	*Trionyx leithi*	*Aspideretes leithii*	Meylan (1987)	-
Trionyx nigricans Anderson, 1875	*Trionyx nigricans*	*Aspideretes nigricans*	Meylan (1987)	Reported from India by Praschag and Gemel (2002)
Trionyx indicus Gray, 1831	*Chitra indica*	*Chitra indica*	-	-
Testudo punctata Bonnaterre, 1789	*Lissemys punctata*	*Lissemys punctata*	-	-
Pelochelys cantorii Gray, 1864	*Pelochelys bibroni*	*Pelochelys cantorii*	Webb (1995)	Smith's (1931: 160) concept was a composite of *Pelochelys cantorii* and *P. bibroni*
AGAMIDAE				
Agama minor Hardwicke & Gray, 1827	*Agama minor*	*Brachysaura minor*	Moody (1980)	-
Agama cristatella Kuhl, 1820	*Calotes cristatellus*	*Bronchocela cristatella*	Moody (1980)	-
Calotes danieli Tiwari & Biswas, 1973	-	*Bronchocela danieli*	Moody (1980)	-
Bronchocela jubata Duméril & Bibron, 1837	*Calotes jubatus*	*Bronchocela jubata*	Moody (1980)	-
Phrynocephalus laungwalansis Sharma, 1978	-	*Bufoniceps laungwalansis*	Arnold (1992)	-
Calotes andamanensis Boulenger, 1891	*Calotes andamanensis*	*Calotes andamanensis*	-	-
Lacerta calotes Linnaeus, 1758	*Calotes calotes*	*Calotes calotes*	-	-

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Calotes ellioti Günther, 1864	*Calotes ellioti*	*Calotes ellioti*	-	-
Calotes Emma Gray, 1845	*Calotes emma*	*Calotes emma*	-	-
Calotes grandisquamis Günther, 1875	*Calotes grandisquamis*	*Calotes grandisquamis*	-	-
Calotes jerdoni Günther, "1870" 1871	*Calotes jerdoni*	*Calotes jerdoni*	-	-
Calotes maria Gray, 1845	*Calotes maria*	*Calotes maria*	-	-
Calotes mystaceus Duméril & Bibron, 1837	*Calotes mystaceus*	*Calotes mystaceus*	-	-
Calotes nemoricola Jerdon, 1853	*Calotes nemoricola*	*Calotes nemoricola*	-	-
Calotes Rouxii Duméril & Bibron, 1837	*Calotes rouxi*	*Calotes rouxii*	-	-
Agama versicolor Daudin, 1802	*Calotes versicolor*	*Calotes versicolor*	-	-
Tiaris subcristata Blyth, 1860	*Goniocephalus subcristatus*	*Coryphophylax subcristatus*	Moody (1980)	-
Draco blanfordii Boulenger, 1885	*Draco blanfordi*	*Draco blanfordii*	-	-
Draco Dussumieri Duméril & Bibron, 1837	*Draco dussumieri*	*Draco dussumieri*	-	-
Japalura andersoniana Annandale, 1905	*Japalura andersoniana*	*Japalura andersoniana*	-	-
Acanthosaura kumaonensis Annandale, 1907	*Japalura kumaonensis*	*Oriotaris kumaonensis*	Kästle and Schleich (1998)	-
Oreocalotes major Jerdon, 1870	*Japalura major*	*Oriotaris major*	Kästle and Schleich (1998)	-
Japalura planidorsata Jerdon, 1870	*Japalura planidorsata*	*Japalura planidorsata*	-	-
Calotes tricarinatus Blyth, 1853	*Japalura tricarinata*	*Oriotaris tricarinata*	Kästle and Schleich (1998)	-
Japalura variegata Gray, 1853	*Japalura variegata*	*Japalura variegata*	-	-

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Stellio agrorensis Stoliczka, 1872	*Agama agrorensis*	*Laudakia agrorensis*	Moody (1980)	-
Stellio caucasius Eichwald, 1831	*Agama caucasica*	*Laudakia caucasia*	Moody (1980)	-
Stellio Dayanus Stoliczka, 1871	*Agama tuberculata*	*Laudakia dayana*	Baig and Böhme (1997)	-
Stellio Himalayanus Steindachner, 1867	*Agama himalayana*	*Laudakia himalayana*	Moody (1980)	As junior synonym of *Agama tuberculata*
Laudakia (?) *melanura* Blyth, 1854	*Agama melanura*	*Laudakia melanura*	Moody (1980)	-
Agama pakistanica Baig, 1989	-	*Laudakia pakistanica*	-	-
A. (=*Agama*) *tuberculata* Hardwicke & Gray, 1827	*Agama tuberculata*	*Laudakia tuberculata*	Moody (1980)	-
Salea austeniana Annandale, 1908	*Mictopholis austeniana*	*Mictopholis austeniana*	-	-
Oriocalotes paulus Smith, 1935	*Oriocalotes paulus*	*Oriocalotes paulus*	-	-
Otocryptis beddomii Boulenger, 1885	*Otocryptis beddomii*	*Otocryptis beddomii*	-	-
Phrynocephalus alticola Peters, 1984	-	*Phrynocephalus alticola*	-	-
Phrynocephalus reticulatus Eichwald, 1831	*Phrynocephalus reticulatus*	*Phrynocephalus theobaldi reticulatus*	-	-
Phrynocephalus Theobaldi Blyth, 1863	*Phrynocephalus theobaldi*	*Phrynocephalus theobaldi*	-	-
Charasia blanfordana Stoliczka, 1871	*Psammophilus blanfordanus*	*Psammophilus blanfordanus*	-	-
Agama Dorsalis Gray in: Griffith & Pidgeon, 1831	*Psammophilus dorsalis*	*Psammophilus dorsalis*	-	-
Calotes microlepis Boulenger, 1887	*Calotes microlepis*	*Pseudocalotes microlepis*	Moody (1980)	-

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Otocryptis (Ptyctolaemus) gularis Peters, 1864	*Ptyctolaemus gularis*	*Ptyctolaemus gularis*	-	-
Lophosalea anamallayana Beddome, 1878	*Salea anamallayana*	*Salea anamallayana*	-	-
Salea Horsfieldii Gray, 1845	*Salea horsfieldi*	*Salea horsfieldii*	-	-
Sit. (=*Sitana*) *ponticeriana* Cuvier, 1829	*Sitana ponticeriana*	*Sitana ponticeriana*	-	-
Agama agilis Olivier, 1804	*Agama agilis*	*Trapelus agilis*	Moody (1980)	-
Trapelus megalonyx Günther, 1864	*Agama megalonyx*	*Trapelus megalonyx*	Moody (1980)	-
ANGUIDAE				
Pseudopus gracilis Gray, 1845	*Ophisaurus gracilis*	*Ophisaurus gracilis*	-	-
CHAMAELEONIDAE				
Chamaeleo zeylanicus Laurenti, 1768	*Chamaeleo zeylanicus*	*Chamaeleo zeylanicus*	-	-
DIBAMIDAE				
Rhinophidion Nicobaricum Steindachner, 1867	*Dibamus novae-guineae*	*Dibamus nicobaricus*	Das (1996)	Smith's (1935: 362) concept was a composite of at least *Dibamus nicobaricus*, *D. alfredi*, *D. novaeguineae* and *D. leucurus*
EUBLEPHARIDAE				
Eublepharis macularius fuscus Börner, 1981	-	*Eublepharis fuscus*	Das (1998)	Elevated to the rank of species by Das (1998)
Eublepharis Hardwickii Gray, 1827	*Eublepharis hardwickii*	*Eublepharis hardwickii*	-	-
Cyrtodactylus macularius Blyth, 1854	*Eublepharis macularius*	*Eublepharis macularius*	-	-
GEKKONIDAE				
Alsophylax (*Altiphylax*) *boehmei* Szczerbak, 1991	-	*Alsophylax boehmei*	-	-

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Calodactylus aureus Beddome, 1870	*Calodactylodes aureus*	*Calodactylodes aureus*	-	-
Cnemaspis assamensis Das & Sengupta, 2000	-	*Cnemaspis assamensis*	-	-
Gymnodactylus Beddomei Theobald, 1876	*Cnemaspis beddomei*	*Cnemaspis beddomei*	-	-
Goniodactylus Boëi Gray, 1842	*Cnemaspis boiei*	*Cnemaspis boei*	-	Illegal emendation of the species name in Smith (1935: 75)
Cnemaspis goaensis Sharma, 1976	-	*Cnemaspis goaensis*	-	-
Gymnodactylus gracilis Beddome, 1870	*Cnemaspis gracilis*	*Cnemaspis gracilis*	-	-
Cnemaspis heteropholis Bauer, 2002	-	*Cnemaspis heteropholis*	-	-
Goniodactylus indicus Gray, 1846	*Cnemaspis indica*	*Cnemaspis indica*	-	-
Cnemaspis indraneildasii Bauer, 2002	*Cnemaspis kandiana* (in part)	*Cnemaspis indraneildasii*	-	Western Ghats populations referred by Smith (1935: 73) to *Cnemaspis kandiana* now *C. indraneildasii* Bauer (2002)
Gymnodactylus Jerdonii Theobald, 1868	*Cnemaspis jerdoni*	*Cnemaspis jerdonii*	-	-
Gymnodactylus Kandianus Kelaart, 1852	*Cnemaspis kandiana*	*Cnemaspis kandiana*	-	Systematic status of most of the Indian (including Andaman and Nicobar Islands) populations under investigation
Gymnodactylus littoralis Jerdon, 1853	*Cnemaspis littoralis*	*Cnemaspis littoralis*	-	-
Gymnodactylus Mysoriensis Jerdon, 1853	*Cnemaspis mysoriensis*	*Cnemaspis mysoriensis*	-	-
Cnemaspis nairi Inger, Marx & Koshy, 1984	-	*Cnemaspis nairi*	-	-

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Gymnodactylus ornatus Beddome, 1870	*Cnemaspis ornata*	*Cnemaspis ornata*	-	-
Cnemaspis otai Das & Bauer, 2000	-	*Cnemaspis otai*	-	-
Gymnodactylus Sisparensis Theobald, 1876	*Cnemaspis sisparensis*	*Cnemaspis sisparensis*	-	-
Cnemaspis kandianus tropidogaster Boulenger, 1885	*Cnemaspis kandiana*	*Cnemaspis tropidogaster*	Inger *et al.* (1984a)	Treated as a junior synonym of *Cnemaspis kandiana* by Smith (1935: 73)
Gymnodactylus Wynadensis Beddome, 1870	*Cnemaspis wynadensis*	*Cnemaspis wynadensis*	-	-
Cnemaspis yercaudensis Das & Bauer, 2000	-	*Cnemaspis yercaudensis*	-	-
Stellio platyurus Schneider, 1792	*Platyurus platyurus*	*Cosymbotus platyurus*	-	-
Stenodactylus orientalis Blanford, 1875	*Stenodactylus orientalis*	*Crossobamon orientalis*	Kluge (1967)	-
Cyrtodactylus adleri Das, 1997	-	*Cyrtodactylus adleri*	-	-
Gymnodactylus chitralensis Smith, 1935	*Gymnodactylus chitralensis*	*Cyrtodactylus chitralensis*	Kluge (1993)	-
Naultinus (?) *fasciolatus* Blyth, 1860	*Gymnodactylus fasciolatus*	*Cyrtodactylus fasciolatus*	Kluge (1993)	-
Gymnodactylus gubernatoris Annandale, 1913	*Gymnodactylus gubernatoris*	*Cyrtodactylus gubernatoris*	Kluge (1993)	-
Cyrtodactylus himalayanus Duda & Sahi, 1978	-	*Cyrtodactylus himalayanus*	Kluge (1993)	-
Pentadactylus Khasiensis Jerdon, 1870	*Gymnodactylus khasiensis*	*Cyrtodactylus khasiensis*	Kluge (1993)	-
Gymnodactylus Lawderanus Stoliczka, 1871	*Gymnodactylus lawderanus*	*Cyrtodactylus lawderanus*	Kluge (1993)	-

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Gymnodactylus malcolmsmithii Constable, 1949	-	*Cyrtodactylus malcolmsmithi*	Kluge (1993)	-
Cyrtodactylus mansarulus Duda & Sahi, 1978	-	*Cyrtodactylus mansarulus*	Kluge (1993)	-
Cyrtodactylus pulchellus Hardwicke & Gray, 1827	*Gymnodactylus pulchellus*	*Cyrtodactylus pulchellus*	Kluge (1993)	Not specifically recorded from India by Smith (1935), but cited on p. 38
Puellula rubida Blyth, 1860	*Gymnodactylus rubidus*	*Cyrtodactylus rubidus*	Kluge (1993)	-
Gymnodactylus stoliczkai Steindachner, 1867	*Gymnodactylus stoliczkai*	*Cyrtodactylus stoliczkai*	Kluge (1993)	-
Gymnodactylus walli Ingoldby, 1922	*Gymnodactylus stoliczkai*	*Cyrtodactylus walli*	Kluge (1993)	Listed as a junior synonym of *Gymnodactylus stoliczkai* by Smith (1935: 57)
Cyrtodactylus aravallensis Gill, 1997	-	*Cyrtopodion aravallensis*	Kluge (2001)	-
Gymnodactylus kachhensis Stoliczka, 1872	*Gymnodactylus kachhensis kachhensis*	*Cyrtopodion kachhense*	Kluge (1993)	-
Gymnodactylus montium-salsorum Annandale, 1913	*Gymnodactylus montium-salsorum*	*Cyrtopodion montiumsalsorum*	Kluge (1993)	-
Stenodactylus scaber von Heyden in: Rüppell, 1827	*Gymnodactylus scaber*	*Cyrtopodion scabrum*	Kluge (1993)	-
Gymnodactylus Collegalensis Beddome, 1870	*Gymnodactylus collegalensis*	*Geckoella collegalensis*	Kluge (1993)	-
Gymnodactylus deccanensis Günther, 1864	*Gymnodactylus dekkanensis*	*Geckoella dekkanensis*	Kluge (1993)	-
Gymnodactylus Jeyporensis Beddome, 1877	*Gymnodactylus jeyporensis*	*Geckoella jeyporensis*	Kluge (1993)	-

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Gymnodactylus nebulosus Beddome, 1870	*Gymnodactylus nebulosus*	*Geckoella nebulosa*	Kluge (1993)	-
Hemidactylus (Peropus) mutilatus Wiegmann, 1834	*Gehyra mutilata*	*Gehyra mutilata*	-	-
Lacerta gecko Linnaeus, 1758	*Gekko gecko*	*Gekko gecko*	-	-
Gecko Smithii Gray, 1842	*Gekko smithi*	*Gekko smithi*	-	-
Gecko Verreauxi Tytler, "1864" 1865	*Gekko smithi*	*Gekko verreauxi*	Ota *et al.* (1991)	-
Gecko Anamalensis Günther, 1875	*Dravidogecko anamallensis*	*Hemidactylus anamallensis*	Bauer and Russell (1995)	-
Doryura Bowringii Gray, 1845	*Hemidactylus bowringi*	*Hemidactylus bowringii*	-	-
Hemidactylus Brookii Gray, 1845	*Hemidactylus brooki*	*Hemidactylus brookii*	-	-
Hemidactylus flaviviridis Rüppell, 1835	*Hemidactylus flaviviridis*	*Hemidactylus flaviviridis*	-	-
Hemidactylus frenatus Duméril & Bibron, 1836	*Hemidactylus frenatus*	*Hemidactylus frenatus*	-	-
Hemidactylus Garnotii Duméril & Bibron, 1836	*Hemidactylus garnoti*	*Hemidactylus garnotii*	-	-
Hemidactylus giganteus Stoliczka, 1871	*Hemidactylus giganteus*	*Hemidactylus giganteus*	-	-
Hemidactylus gracilis Blanford, 1870	*Hemidactylus gracilis*	*Hemidactylus gracilis*	-	-
Doryura karenorum Theobald, 1868	*Hemidactylus karenorum*	*Hemidactylus karenorum*	-	-
Hemidactylus leschenaultii Duméril & Bibron, 1836	*Hemidactylus leschenaulti*	*Hemidactylus leschenaultii*	-	-
Hemidactylus maculatus Duméril & Bibron, 1836	*Hemidactylus maculatus*	*Hemidactylus maculates*	-	-
Hemidactylus mahendrai Shukla, 1983	-	*Hemidactylus mahendrai*	-	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Hemidactylus porbandarensis Sharma, 1981	-	*Hemidactylus porbandarensis*	-	-
Hemidactylus prashadi Smith, 1935	*Hemidactylus prashadi*	*Hemidactylus prashadi*	-	-
Hemidactylus reticulatus Beddome, 1870	*Hemidactylus reticulatus*	*Hemidactylus reticulates*	-	-
Teratolepis scabriceps Annandale, 1906	*Lophopholis scabriceps*	*Hemidactylus scabriceps*	Loveridge (1947)	-
Hemidactylus subtriedrus Jerdon, 1853	*Hemidactylus subtriedrus*	*Hemidactylus subtriedrus*	-	-
Gecko triedrus Daudin, 1802	*Hemidactylus triedrus*	*Hemidactylus triedrus*	-	-
Hemidactylus aurantiacus Beddome, 1870	*Hemiphyllodactylus typus aurantiacus*	*Hemiphyllodactylus aurantiacus*	Bauer and Das (1999)	-
Hemiphyllodactylus typus Bleeker, 1860	*Hemiphyllodactylus typus typus*	*Hemiphyllodactylus typus*	-	-
Platydactylus Lugubris Duméril & Bibron, 1836	*Lepidodactylus lugubris*	*Lepidodactylus lugubris*	-	As currently understood, a species complex, with both bisexual and unisexual populations
Phelsuma andamanense Blyth, 1860	*Phelsuma andamanense*	*Phelsuma andamanense*	-	-
Ptychozoon kuhli Stejneger, 1902	*Ptychozoon kuhli*	*Ptychozoon kuhli*	-	Replacement name for *Lacerta homalocephala* Creveld, 1809
Ptychozoon homalocephalum Var. *lionotum* Annandale, 1905	*Ptychozoon lionotum*	*Ptychozoon lionotum*	-	-
Hemidactylus albofasciatus Grandison & Soman, 1963	-	*Teratolepis albofasciatus*	-	-
LACERTIDAE				
Acanthodactylus cantoris Günther, 1864	*Acanthodactylus cantoris cantoris*	*Acanthodactylus cantoris*	-	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Eremias [*Mesalina*] *Watsonana* Stoliczka, 1872	*Eremias guttulata watsonana*	*Mesalina watsonana*	Arnold (1986); Anderson (1999)	-
Pseudophiops Beddomei Jerdon, 1870	*Ophisops beddomei*	*Ophisops beddomei*	-	-
Ophisops Jerdoni Blyth, 1853	*Ophisops jerdoni*	*Ophisops jerdoni*	-	-
Lacerta Leschenaultii Milne-Edwards, 1829	*Ophisops leschenaultii*	*Ophisops leschenaultii*	-	-
Ophiops [*Gymnops*] *Microlepis* Blanford, 1870	*Ophisops microlepis*	*Ophisops microlepis*	-	-
Cabrita jerdoni minor Deraniyagala, 1971	*Cabrita jerdoni*	*Ophisops minor*	Arnold (1989); Böhme and Bischoff (1991)	-
Tachydromus Haughtonianus Jerdon, 1870	*Takydromus haughtonianus*	*Takydromus haughtonianus*	-	-
Tachydromus khasiensis Boulenger, 1917	*Takydromus sexlineatus khasiensis*	*Takydromus khasiensis*	-	-
Takydromus sexlineatus Daudin, 1802	*Takydromus sexlineatus*	*Takydromus sexlineatus*	-	-
SCINCIDAE				
Blepharosteres Grayanus Stoliczka, 1872	*Ablepharus grayanus*	*Ablepharus grayanus*	-	-
Sc. (=*Scincus*) *pannonicus* Lichtenstein, 1823	*Ablepharus pannonicus*	*Ablepharus pannonicus*	-	-
Eumeces himalayanus Günther, 1864	*Leiolopisma himalayanum*	*Asymblepharus himalayanum*	Eremchenko and Szczerbak (1980)	-
Eumeces ladacensis Günther, 1864	*Leiolopisma ladacense*	*Asymblepharus ladacensis*	Eremchenko and Szczerbak (1980)	-
Mocoa Sikimmensis Blyth, 1853	*Leiolopisma sikkimense*	*Asymblepharus sikimmensis*	Eremchenko and Szczerbak (1980)	-
Lygosoma himalayanum var. *tragbulensis* Alcock, "1897" 1898	-	*Asymblepharus tragbulense*	Das *et al.* (1998)	Not included in Smith (1935).

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Barkudia insularis Annandale, 1917	*Barkudia insularis*	*Barkudia insularis*	-	-
Anguis melanosticta Schneider, 1801	-	*Barkudia melanosticta*	Das (2000)	Not included in Smith (1943)
Sphenomorphus? pentadactylus Beddome, 1870	*Chalcides pentadactylus*	*Chalcides pentadactylus*	-	-
Euprepes halianus Haly & Nevill in: Nevill, 1887	*Dasia halianus*	*Dasia halianus*	-	-
Dasia nicobarensis Biswas & Sanyal, 1977	-	*Dasia nicobarensis*	-	-
Dasia olivacea Gray, 1839	*Dasia olivacea*	*Dasia olivacea*	-	-
Lygosoma subcaeruleum Boulenger, 1891	*Dasia subcaerulea*	*Dasia subcaeruleum*	-	-
Eumeces poonaensis Sharma, 1970	-	*Eurylepis poonaensis*	Griffith *et al.* (2000)	-
Eurylepis taeniolatus Blyth, 1854	*Eumeces taeniolatus*	*Eurylepis taeniolatus*	Griffith *et al.* (2000)	-
Mocoa macrotympanum Stoliczka, 1873	*Leiolopisma macrotympanum*	*Lipinia macrotympana*	Greer (1974)	-
Riopa albopunctata Gray, 1846	*Riopa albopunctata*	*Lygosoma albopunctata*	Greer (1977)	-
Riopa ashwamedhi Sharma, 1969	-	*Lygosoma ashwamedhi*	-	-
Eumeces bowringii Günther, 1864	*Riopa bowringi*	*Lygosoma bowringii*	Greer (1977)	-
Riopa goaensis Sharma, 1976	-	*Lygosoma goaensis*	-	-
Eumeces Güntheri Peters, 1879	*Riopa guentheri*	*Lygosoma guentheri*	Greer (1977)	-
Chiamela lineata Gray, 1839	*Riopa lineata*	*Lygosoma lineata*	Greer (1977)	-
Riopa pruthi Sharma, 1977	-	*Lygosoma pruthi*	-	-
Scincus punctatus Gmelin, 1799	*Riopa punctata*	*Lygosoma punctata*	Greer (1977)	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Mabuya allapallensis Schmidt, 1926	*Mabuya macularia*	*Mabuya allapallensis*	-	Junior synonym of *Mabuya macularia* in Smith (1935: 264)
Mabuya andamanensis Smith, 1935	*Mabuya andamanensis*	*Mabuya andamanensis*	-	-
Euprepes Beddomei Jerdon, 1870	*Mabuya beddomii*	*Mabuya beddomei*	-	-
Tiliqua Bibronii Gray, "1838" 1839	*Mabuya bibroni*	*Mabuya bibronii*	-	-
Scincus Carinatus Schneider, 1801	*Mabuya carinata*	*Mabuya carinata*	-	-
Mabuya clivicola Inger, Shaffer, Koshy & Bakde, 1984	-	*Mabuya clivicola*	-	-
Euprepes dissimilis Hallowell, 1857	*Mabuya dissimilis*	*Mabuya dissimilis*	-	-
Mabuya gansi Das, 1991	-	*Mabuya gansi*	-	-
Euprepes innotatus Blanford, 1870	*Mabuya innotata*	*Mabuya innotata*	-	-
Euprepes macularius Blyth, 1853	*Mabuya macularia*	*Mabuya macularia*	-	-
Scincus multifasciatus Kuhl, 1820	*Mabuya multifasciata multifasciata*	*Mabuya multifasciata*	-	-
Mabuya nagarjuni Sharma, 1969	-	*Mabuya nagarjuni*	-	-
Euprepes novem-carinatus Anderson, 1871	*Mabuya novemcarinata*	*Mabuya novemcarinata*	-	-
Mabuia quadricarinata Boulenger, 1887	*Mabuya quadricarinata*	*Mabuya quadricarinata*	-	-
Mabuya rudis Boulenger, 1887	*Mabuya multifasciata rudis*	*Mabuya rudis*	-	-
Tiliqua rugifera Stoliczka, 1870	*Mabuya rugifera*	*Mabuya rugifera*	-	-
T. (= *Tiliqua*) *trivittata* Hardwicke & Gray, 1827	*Mabuya trivittata*	*Mabuya trivittata*	-	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Scincus Tytlerii Tytler in: Theobald, 1868	*Mabuya tytleri*	*Mabuya tytlerii*	-	-
Scincus Schneiderii Daudin, 1802	*Eumeces schneideri*	*Novoeumeces schneiderii*	Griffith *et al.* (2000)	-
Ophiomorus raithmai Anderson & Leviton, 1966	-	*Ophiomorus raithmai*	Smith's (1935: 346-347) concept was a composite of *Ophiomorus tridactylus* and *O. raithmai*	
Ristella beddomii Boulenger, 1887	*Ristella beddomii*	*Ristella beddomii*	-	-
Ristella guentheri Boulenger, 1887	*Ristella guentheri*	*Ristella guentheri*	-	-
Ristella Rurkii Gray, 1839	*Ristella rurki*	*Ristella rurkii*	-	-
Ateuchosaurus Travancoricus Beddome, 1870	*Ristella travancorica*	*Ristella travancoricus*	-	-
Lygosoma beddomii Boulenger, 1887	*Leiolopisma beddomei*	*Scincella beddomii*	Greer (1974); Ouboter (1986)	-
Mocoa bilineata Gray, 1846	*Leiolopisma bilineatum*	*Scincella bilineatum*	Greer (1974); Ouboter (1986)	-
Lygosoma laterimaculatum Boulenger, 1887	*Leiolopisma laterimaculatum*	*Scincella laterimaculatum*	Greer (1974); Ouboter (1986)	-
Euprepes macrotis Steindachner, 1867	*Leiolopisma macrotis*	*Scincella macrotis*	Greer (1974); Ouboter (1986)	-
Lygosoma (*Leiolopisma*) *travancoricum* var. *palnica* Boettger, 1892	*Leiolopisma palnicum*	*Scincella palnicum*	Greer (1974); Ouboter (1986)	-
Mocoa Travancorica Beddome, 1870	*Leiolopisma travancoricum*	*Scincella travancoricum*	Greer (1974); Ouboter (1986)	-
Sepsophis punctatus Beddome, 1870	*Sepsophis punctatus*	*Sepsophis punctatus*	-	-
Lygosoma courcyanum Annandale, 1912	*Lygosoma courcyanum*	*Sphenomorphus courcyanum*	-	-
Lygosoma Dussumieri Duméril & Bibron, 1839	*Lygosoma dussumieri*	*Sphenomorphus dussumieri*	-	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Hinulia Indica Gray, 1853	*Lygosoma indicum indicum*	*Sphenomorphus indicus*	-	-
Lissonota maculata Blyth, 1853	*Lygosoma maculatum*	*Sphenomorphus maculatus*	-	-
Tropidophorus assamensis Annandale, 1912	*Tropidophorus assamensis*	*Tropidophorus assamensis*	-	-
UROMASTYCIDAE				
U. (=*Uromastyx*) *Hardwickii* Gray in: Hardwicke & Gray, 1827	*Uromastix hardwickii*	*Uromastyx hardwickii*	-	Allocated by Smith (1935: 244) to the Agamidae
VARANIDAE				
Tupinambis bengalensis Daudin, 1802	*Varanus monitor*	*Varanus bengalensis*	Mertens (1946); Sprackland (1982)	-
M. (= *Monitor*) *flavescens* Hardwicke & Gray, 1827	*Varanus flavescens*	*Varanus flavescens*	-	-
Tupinambis griseus Daudin, 1803	*Varanus griseus*	*Varanus griseus*	-	-
Stellio salvator Laurenti, 1768	*Varanus salvator*	*Varanus salvator*	-	-
ACROCHORDIDAE				
Hydrus Granulatus Schneider, 1799	*Acrochordus granulatus*	*Acrochordus granulatus*	-	-
BOIDAE				
Boa Conica Schneider, 1801	*Eryx conicus*	*Eryx conicus*	-	-
Boa Johnii Russell, 1801	*Eryx johni*	*Eryx johnii*	-	-
Eryx whitakeri Das, 1991	-	*Eryx whitakeri*	-	-
Coluber Molurus Linnaeus, 1758	*Python molurus*	*Python molurus*	-	-
Boa Reticulata Schneider, 1801	*Python reticulatus*	*Python reticulatus*	-	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
COLUBRIDAE				
Tragops dispar Günther, 1864	*Dryophis dispar*	*Ahaetulla dispar*	-	-
Dryophis fronticinctus Günther, 1858	*Dryophis fronticinctus*	*Ahaetulla fronticincta*	-	-
Coluber nasuta Lacepède, 1789	*Dryophis nasutus*	*Ahaetulla nasuta*	-	-
Psammophis Perroteti Duméril, Bibron & Duméril, 1854	*Dryophis perroteti*	*Ahaetulla perroteti*	-	-
Dryophis prasina Boie, 1827	*Dryophis prasinus*	*Ahaetulla prasina*	-	-
Dryinus pulverulentus Duméril, Bibron & Duméril, 1854	*Dryophis pulverulentus*	*Ahaetulla pulverulenta*	-	-
Tropidonotus beddomii Günther, 1864	*Natrix beddomei*	*Amphiesma beddomii*	Malnate (1960)	-
Tropidonotus khasiensis Boulenger, 1890	*Natrix khasiensis*	*Amphiesma khasiense*	Malnate (1960)	-
Tropidonotus modestus Günther, 1875	*Natrix modesta*	*Amphiesma modestum*	Malnate (1960)	-
Tropidonotus monticolus Jerdon, 1853	*Natrix monticola*	*Amphiesma monticola*	Malnate (1960)	-
Tropidonotus nicobarensis Sclater, 1891	*Natrix nicobarensis*	*Amphiesma nicobarense*	Malnate (1960)	-
Tropidonotus parallelus Boulenger, 1890	*Natrix parallela*	*Amphiesma parallelum*	Malnate (1960)	-
Tropidonotus pealii Sclater, 1891	*Natrix peali*	*Amphiesma pealii*	Malnate (1960)	-
Tropidonotus platyceps Blyth, 1854	*Natrix platyceps*	*Amphiesma platyceps*	Malnate (1960)	-
Herpetoreas sieboldii Günther, 1860	*Natrix platyceps*	*Amphiesma sieboldii*	Malnate (1960); also, Malnate (1966)	-
Coluber stolatus Linnaeus, 1758	*Natrix stolata*	*Amphiesma stolatum*	Malnate (1960)	-
Tropidonotus venningi Wall, 1910	*Natrix venningi*	*Amphiesma venningi*	Malnate (1960)	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Tropidonotus xenura Wall, 1907	*Natrix xenura*	*Amphiesma xenura*	Malnate (1960)	-
Coluber Fasciolatus Shaw, 1802	*Coluber fasciolatus*	*Argyrogena fasciolata*	Wilson (1967)	-
Coluber schistosus Daudin, 1803	*Atretium schistosum*	*Atretium schistosum*	-	-
Calamaria reticulata Blyth, 1854	*Blythia reticulata*	*Blythia reticulata*	-	-
Dipsas andamanensis Wall, 1909	*Boiga ceylonensis andamanensis*	*Boiga andamanensis*	-	-
Dipsas beddomei Wall, 1909	*Boiga ceylonensis beddomei*	*Boiga beddomei*	-	-
Dipsadomorphus ceylonensis Günther, 1858	*Boiga ceylonensis ceylonensis*	*Boiga ceylonensis*	-	-
Triglyphodon Cyaneum Duméril, Bibron & Duméril, 1854	*Boiga cyanea*	*Boiga cyanea*	-	-
Dipsas dightoni Boulenger, 1894	*Boiga dightoni*	*Boiga dightoni*	-	-
Triglyphodon Forsteni Duméril, Bibron & Duméril, 1854	*Boiga forsteni*	*Boiga forsteni*	-	-
Dipsas gokool Gray, 1835	*Boiga gokool*	*Boiga gokool*	-	-
Dipsas multifasciata Blyth, "1860" 1861	*Boiga multifasciata*	*Boiga multifasciata*	-	-
Dipsas multomaculata Boie, 1827	*Boiga multimaculata*	*Boiga multomaculata*	-	-
Dipsas nuchalis Günther, 1875	*Boiga ceylonensis nuchalis*	*Boiga nuchalis*	-	-
Boiga ocellata Kroon, 1973	-	*Boiga ocellata*	-	Smith's (1943: 357-358) concept of *B. cynodon* was a composite of this nominal species and *B. ocellata* Kroon, 1973
Dipsas ochraceus Günther, 1868	*Boiga ochracea*	*Boiga ochraceus*	-	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Dipsadomorphus quinqunciatus Wall, 1908	*Boiga quincunciata*	*Boiga quincunciata*	-	-
Coluber trigonatus Schneider in: Bechstein, 1802	*Boiga trigonata*	*Boiga trigonata*	-	-
Boiga wallachi Das, 1997	-	*Boiga wallachi*	-	-
Calamaria pavimentata Duméril, Bibron & Duméril, 1854	*Calamaria pavimentata*	*Calamaria pavimentata*	-	-
Coronella violacea Cantor, 1839	*Cantoria violacea*	*Cantoria violacea*	-	-
Hydrus Rynchops Schneider, 1799	*Cerberus rhynchops*	*Cerberus rynchops*	-	Illegal emendation to *rhynchops* by Boulenger (1896)
Coluber Ornatus Shaw, 1802	*Chrysopelea ornata*	*Chrysopelea ornata*	-	-
Chrysopelea paradisi Boie in: Boie, 1827	*Chrysopelea paradisi*	*Chrysopelea paradisi*	-	-
Coluber flavolineata Schlegel, 1827	*Elaphe flavolineata*	*Coelognathus flavolineatus*	Helfenberger (2001a, b)	-
Coluber helena Daudin, 1803	*Elaphe helena*	*Coelognathus helena*	Helfenberger (2001a, b)	-
Coluber radiatus Schlegel, 1837	*Elaphe radiata*	*Coelognathus radiatus*	Helfenberger (2001a, b)	-
Coluber bholanathi Sharma, 1976	-	*Coluber bholanathi*	-	-
Zamenis gracilis Günther, 1862	*Coluber gracilis*	*Coluber gracilis*	-	-
Coluber Ravergieri Ménétriés, 1832	*Coluber ravergieri*	*Coluber ravergieri*	-	-
Zamenis ladacensis Anderson, 1871	*Coluber rhodorhachis*	*Coluber ladacensis*	Ataev *et al.* (1994)	-
Coluber ventromaculatus Gray, 1834	*Coluber ventromaculatus*	*Coluber ventromaculatus*	-	-
Coluber vittacaudatus Blyth, 1854	-	*Coluber vittacaudatus*	-	Not included in Smith (1943)

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Zamenis brachyurus Günther, 1866	*Coronella brachyura*	*Coronella brachyura*	-	-
Cyclophiops doriae Boulenger, 1888	*Opheodrys doriæ*	*Cyclophiops doriae*	Cundall (1981)	-
Dendrophis pictus Variety *cyanochloris* Wall, 1921	*Ahaetulla cyanochloris*	*Dendrelaphis cyanochloris*	International Commission on Zoological Nomenclature (1958); Savage (1952)	-
Dendrophis gorei Wall, 1910	*Ahaetulla gorei*	*Dendrelaphis gorei*	-	-
Dendrophis grandoculis Boulenger, 1890	*Ahaetulla grandoculis*	*Dendrelaphis grandoculis*	-	-
Dendrelaphis humayuni Tiwari & Biswas, 1973	-	*Dendrelaphis humayuni*	-	-
Coluber pictus Gmelin, 1789	*Ahaetulla ahaetulla*	*Dendrelaphis pictus*	-	-
Dendrophis subocularis Boulenger, 1888	*Ahaetulla subocularis*	*Dendrelaphis subocularis*	-	-
Coluber tristis Daudin, 1803	*Ahaetulla tristis*	*Dendrelaphis tristis*	-	-
Ophites gammiei Blanford, 1878	*Dinodon gammiei*	*Dinodon gammiei*	-	-
Ophites septentrionalis Günther, 1875	*Dinodon septentrionalis*	*Dinodon septentrionalis*	-	-
Odontomus gracilis Günther, 1864	*Dryocalamus gracilis*	*Dryocalamus gracilis*	-	-
Coluber nympha Daudin, 1803	*Dryocalamus nympha*	*Dryocalamus nympha*		
Elachistodon westermanni Reinhardt, 1863	*Elachistodon westermanni*	*Elachistodon westermanni*	-	-
Herpetrodryas frenatus Gray, 1853	*Elaphe frenata*	*Elaphe frenata*	-	-
Coluber prasinus Blyth, 1854	*Elaphe prasina*	*Elaphe prasina*	-	-
Coluber mandarinus Cantor, 1842	*Elaphe mandarina*	*Euprepiophis mandarinus*	Utiger *et al.* (2002)	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Eurostus Dussumierii Duméril, Bibron & Duméril, 1854	*Enhydris dussumieri*	*Enhydris dussumierii*	-	-
Hydrus Enhydris Schneider, 1799	*Enhydris enhydris*	*Enhydris enhydris*	-	-
Homalopsis sieboldii Schlegel, 1837	*Enhydris sieboldi*	*Enhydris sieboldii*	-	-
Homalopsis leucobalia Schlegel, 1837	*Fordonia leucobalia*	*Fordonia leucobalia*	-	-
Coluber (*Homalopsis*) *prevostianus* Eydoux & Gervais, 1837	*Gerardia prevostiana*	*Gerarda prevostiana*	-	-
Ablabes Nicobariensis Stoliczka, 1870	*Liopeltis nicobariensis*	*Gongylosoma nicobariense*	Leviton (1964)	-
Coluber Oxycephalus Boie, 1827	*Elaphe oxycephala*	*Gonyosoma oxycephalum*	Dowling (1958)	-
Coluber buccatus Linnaeus, 1758	*Homalopsis buccata*	*Homalopsis buccata*	-	-
Cyclophis calamaria Günther, 1858	*Liopeltis calamaria*	*Liopeltis calamaria*	-	-
Cyclophis frenatus Günther, 1858	*Liopeltis frenatus*	*Liopeltis frenatus*	-	-
Ablabes rappii Günther, 1860	*Liopeltis rappi*	*Liopeltis rappii*	-	-
Ablabes stoliczkae Sclater, 1891	*Liopeltis stoliczkae*	*Liopeltis stoliczkae*	-	-
Coluber aulicus Linnaeus, 1758	*Lycodon aulicus*	*Lycodon aulicus*	-	-
Lycodon capucinus Boie, 1827	*Lycodon aulicus capucinus*	*Lycodon capucinus*	Arnold (2000); Fritts (1993); Jones (1993)	-
Ophites fasciatus Anderson, "1878" 1879	*Lycodon fasciatus*	*Lycodon fasciatus*	-	-
Lycodon flavomaculatus Wall, 1907	*Lycodon flavomaculatus*	*Lycodon flavomaculatus*	-	-
Coluber Jara Shaw, 1802	*Lycodon jara*	*Lycodon jara*	-	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Lycodon laoensis Günther, 1864	*Lycodon laoensis*	*Lycodon laoensis*	-	-
Lycodon mackinnoni Wall, 1906	*Lycodon mackinnoni*	*Lycodon mackinnoni*	-	-
Coluber Striatus Shaw, 1802	*Lycodon striatus*	*Lycodon striatus*	-	-
Lycodon tiwarii Biswas & Sanyal, 1965	-	*Lycodon tiwarii*	-	-
Cercaspis Travancoricus Beddome, 1870	*Lycodon travancoricus*	*Lycodon travancoricus*	-	-
Lycodon zawi Slowinski, Pawar, Win, Thin, Gyi, Oo & Tun, 2001	-	*Lycodon zawi*	-	-
Tropidonotus plumbicolor Cantor, 1839	*Macropisthodon plumbicolor*	*Macropisthodon plumbicolor*	-	-
Oligodon affinis Günther, 1862	*Oligodon affinis*	*Oligodon affinis*	-	-
Coronella albocincta Cantor, 1839	*Oligodon albocinctus*	*Oligodon albocinctus*	-	-
Coluber Arnensis Shaw, 1802	*Oligodon arnensis*	*Oligodon arnensis*	-	-
Oligodon brevicauda Günther, 1862	*Oligodon brevicauda*	*Oligodon brevicauda*	-	-
Calamaria catenata Blyth, 1854	*Oligodon catenata*	*Oligodon catenatus*	-	-
Simotes cinereus Günther, 1864	*Oligodon cinereus*	*Oligodon cinereus*	-	-
Coronella cyclura Cantor, 1839	*Oligodon cyclurus*	*Oligodon cyclurus*	-	-
Elaps dorsalis Gray, 1835	*Oligodon dorsalis*	*Oligodon dorsalis*	-	-
Simotes albocinctus (variety) *dorsolateralis* Wall, 1909	*Oligodon cyclurus*	*Oligodon dorsolateralis*	-	-
Oligodon erythrogaster Boulenger, 1907	*Oligodon erythrogaster*	*Oligodon erythrogaster*	-	-
Oligodon erythrorhachis Wall, 1910	*Oligodon erythrorhachis*	*Oligodon erythrorhachis*	-	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Simotes juglandifer Wall, 1909	*Oligodon juglandifer*	*Oligodon juglandifer*	-	-
Oligodon kheriensis Acharji & Ray, 1936	*Oligodon cyclurus*	*Oligodon kheriensis*	Schleich and Kästle (2002)	-
Oligodon melaneus Wall, 1909	*Oligodon melaneus*	*Oligodon melaneus*	-	-
Oligodon melazonotus Wall, 1922	*Oligodon melazonotus*	*Oligodon melazonotus*	-	-
Oligodon nikhili Whitaker & Dattatri, 1982	-	*Oligodon nikhili*	-	-
Coronella taeniolata Jerdon, 1853	*Oligodon taeniolatus*	*Oligodon taeniolatus*	-	-
Simotes Theobaldi Günther, 1868	*Oligodon theobaldi*	*Oligodon theobaldi*	-	-
Oligodon travancoricum Beddome, 1877	*Oligodon travancoricus*	*Oligodon travancoricus*	-	-
Xenodon venustum Jerdon, 1853	*Oligodon venustus*	*Oligodon venustus*	-	-
Simotes wood-masoni Sclater, 1891	*Oligodon woodmasoni*	*Oligodon woodmasoni*	-	-
Coluber porphyracea Cantor, 1839	*Elaphe porphyracea*	*Oreophis porphyraceus*	Utiger *et al.* (2002)	-
Coluber cantoris Boulenger, 1894	*Elaphe cantoris*	*Orthriophis cantoris*	Utiger *et al.* (2002)	-
Spilotes hodgsonii Günther, 1860	*Elaphe hodgsoni*	*Orthriophis hodgsonii*	Utiger *et al.* (2002)	-
Elaphe taeniurus Cope, "1860" 1861	*Elaphe tæniura*	*Orthriophis taeniurus*	Utiger *et al.* (2002)	-
Pareas macularius Blyth in: Theobald, 1868	*Pareas macularius*	*Pareas macularius*	-	-
Dipsas monticola Cantor, 1839	*Pareas monticola*	*Pareas monticolus*	-	-
Psammophis pulverulenta Boie in: Boie, 1827	*Psammodynastes pulverulentus*	*Psammodynastes pulverulentus*	-	-
Coluber Condanarus Merrem, 1820	*Psammophis condanarus*	*Psammophis condanarus*	-	-
Psammophis leithii Günther, 1869	*Psammophis leithi*	*Psammophis leithii*	-	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Psammophis longifrons Boulenger, 1890	*Psammophis longifrons*	*Psammophis longifrons*	-	-
Coluber schokari Forskål, 1775	*Psammophis schokari*	*Psammophis schokari*	-	-
Tropidonotus macrops Blyth, 1854	*Pseudoxenodon macrops*	*Pseudoxenodon macrops*	-	-
Coluber korros Schlegel, 1837	*Ptyas korros*	*Ptyas korros*	-	-
Coluber mucosus Linnaeus, 1758	*Ptyas mucosus*	*Ptyas mucosa*	David and Das (in press)	-
Coluber nigromarginatus Blyth, 1854	*Zaocys nigromarginatus*	*Ptyas nigromarginata*	David and Das (in press)	-
Tropidonotus himalayanus Günther, 1864	*Natrix himalayana*	*Rhabdophis himalayanus*	Malnate (1960)	-
Tropidonotus subminiatus Schlegel, 1837	*Natrix subminiata*	*Rhabdophis subminiatus*	Malnate (1960)	-
Calamaria bicolor Blyth, 1854	*Rhabdops bicolor*	*Rhabdops bicolor*	-	-
Ablabes olivaceus Beddome, 1863	*Rhabdops olivaceus*	*Rhabdops olivaceus*	-	-
Ablabes bistrigatus Günther, 1868	*Sibynophis bistrigatus*	*Sibynophis bistrigatus*	-	-
Psammophis collaris Gray, 1853	*Sibynophis collaris*	*Sibynophis collaris*	-	-
Calamaria sagittaria Cantor, 1839	*Sibynophis sagittarius*	*Sibynophis sagittaria*	-	-
Tropidonotus percarinatus Boulenger, 1899	*Natrix percarinata*	*Sinonatrix percarinata*	Rossman and Eberle (1977)	-
Zamenis arenarius Boulenger, 1890	*Coluber arenarius*	*Spalerosophis arenarius*	Marx (1959)	-
Zamenis diadema var. *atriceps* Fischer, 1885	*Coluber diadema*	*Spalerosophis atriceps*	-	-
Coluber diadema Schlegel, 1837	*Coluber diadema*	*Spalerosophis diadema*	Marx (1959)	-
Stoliczkia Khasiensis Jerdon, 1870	*Stoliczkaia khasiensis*	*Stoliczkia khasiensis*	-	-
Calamaria fusca Blyth, 1854	*Trachischium fuscum*	*Trachischium fuscum*		

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Trachischium guentheri Boulenger, 1890	*Trachischium guentheri*	*Trachischium guentheri*	-	-
Trachischium laeve Peracca, 1904	*Trachischium læve*	*Trachischium leave*	-	-
Calamaria monticola Cantor, 1839	*Trachischium monticola*	*Trachischium monticola*	-	-
Calamaria tenuiceps Blyth, 1854	*Trachischium tenuiceps*	*Trachischium tenuiceps*	-	-
Psammophis cerasogaster Cantor, 1839	*Xenochrophis cerasogaster*	*Xenochrophis cerasogaster*	-	-
Amphiesma flavipunctatum Hallowell, 1860	*Natrix piscator flavipunctata*	*Xenochrophis flavipunctatus*	Taylor (1965)	-
Coluber melanzostus Gravenhorst, 1807	*Natrix piscator melanzostus*	*Xenochrophis melanzostus*	Malnate and Underwood (1988)	-
Hydrus Piscator Schneider, 1799	*Natrix piscator*	*Xenochrophis piscator*	Malnate and Underwood (1988)	-
Tropidonotus punctulatus Günther, 1858	*Natrix punctulata*	*Xenochrophis punctulatus*	Malnate and Underwood (1988)	-
Tropidonotus sancti-johannis Boulenger, 1890	*Natrix piscator*	*Xenochrophis sanctijohannis*	Khan (1984a)	-
Tropidonotus Trianguligerus Boie, 1827	*Natrix trianguligera*	*Xenochropis trianguligerus*	Malnate and Underwood (1988)	-
Platypteryx Perroteti Duméril, Bibron & Duméril, 1854	*Xylophis perroteti*	*Xylophis perroteti*	-	-
Geophis stenorhynchus Günther, 1875	*Xylophis stenorhynchus*	*Xylophis stenorhynchus*	-	-
ELAPIDAE				
Bungarus andamanensis Biswas & Sanyal, 1978	-	*Bungarus andamanensis*	-	-

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Elaps bungaroides Cantor, 1839	*Bungarus bungaroides*	*Bungarus bungaroides*	-	-
Pseudoboa Caerulea Schneider, 1801	*Bungarus cæruleus*	*Bungarus caeruleus*	-	-
Pseudoboa Fasciata Schneider, 1801	*Bungarus fasciatus*	*Bungarus fasciatus*	-	-
Bungarus lividus Cantor, 1839	*Bungarus lividus*	*Bungarus lividus*	-	-
Bungarus niger Wall, 1909	*Bungarus niger*	*Bungarus niger*	-	-
Bungarus sindanus Boulenger, 1897	*Bungarus walli*	*Bungarus sindanus*	Khan (1984b)	-
Callophis beddomei Smith, 1943	*Callophis beddomei*	*Calliophis beddomei*	-	-
Elaps Bibroni Jan, 1858	*Callophis bibroni*	*Calliophis bibroni*	-	-
Coluber Melanurus Shaw, 1802	*Callophis melanurus*	*Calliophis melanurus*	-	-
Callophis nigrescens Günther, 1862	*Callophis nigrescens*	*Calliophis nigrescens*	-	-
Naja kaouthia Lesson, 1831	*Naja naja kaouthia*	*Naja kaouthia*	Wüster (1998a); Wüster and Thorpe (1992)	-
Coluber naja Linnaeus, 1758	*Naja naja naja*	*Naja naja*	Wüster (1998a); Wüster and Thorpe (1992)	-
Tomyris oxiana Eichwald, 1831	*Naja naja oxiana*	*Naja oxiana*	Wüster (1998a); Wüster and Thorpe (1992)	-
Naja tripudians var. *sagittifera* Wall, 1913	*Naja naja kaouthia*	*Naja sagittifera*	Wüster (1998a)	-
Hamadryas hannah Cantor, 1836	*Naja hannah*	*Ophiophagus hannah*	Bogert (1945)	-
Elaps Macclellandi Reinhardt, 1844	*Callophis macclellandi*	*Sinomicrurus macclellandi*	Slowinski *et al.* (2001a)	-
HYDROPHIIDAE *Hydrus Stokesii* Gray in: Stokes, 1846	*Astrotia stokesi*	*Astrotia stokesii*	-	-

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Hydrophis schistosus Daudin, 1803	*Enhydrina schistose*	*Enhydrina schistosa*	-	-
Hydrus Caerulescens Shaw, 1802	*Hydrophis cærulescens*	*Hydrophis caerulescens*	-	-
Hydrophis cantoris Günther, 1864	*Microcephalophis cantoris*	*Hydrophis cantoris*	Rasmussen (1996)	-
Hydrophis cyanocinctus Daudin, 1803	*Hydrophis cyanocinctus*	*Hydrophis cyanocinctus*	-	-
Hydrus Fasciatus Schneider, 1799	*Hydrophis fasciatus*	*Hydrophis fasciatus*	-	-
Hydrus Gracilis Shaw, 1802	*Microcephalophis gracilis*	*Hydrophis gracilis*	Rasmussen (1996)	-
Aturia Lapemoides Gray, 1849	*Hydrophis lapemoides*	*Hydrophis lapemoides*	-	-
Anguis mamillaris Daudin, 1803	*Hydrophis mamillaris*	*Hydrophis mamillaris*	-	-
Hydrophis nigrocinctus Daudin, 1803	*Hydrophis nigrocinctus*	*Hydrophis nigrocinctus*	-	-
Hydrophis obscurus Daudin, 1803	*Hydrophis obscurus*	*Hydrophis obscurus*	-	-
Pelamis ornata Gray, 1842	*Hydrophis ornatus*	*Hydrophis ornatus*	-	-
Hydrus Spiralis Shaw, 1802	*Hydrophis spiralis*	*Hydrophis spiralis*	-	-
Hydrophis stricticollis Günther, 1864	*Hydrophis stricticollis*	*Hydrophis stricticollis*	-	-
Kerilia Jerdonii Gray, 1849	*Kerilia jerdoni*	*Kerilia jerdonii*	-	-
Lapemis hardwickii Gray, 1834	*Lapemis hardwickii*	*Lapemis curtus*	Gritis and Voris (1990)	-
Hydrus Curtus Shaw, 1802	*Lapemis curtus*	*Lapemis curtus*	-	-
Hydrus Colubrinus Schneider, 1799	*Laticauda colubrina*	*Laticauda colubrina*	-	-
Coluber laticaudata Linnaeus, 1758	*Laticauda laticaudata*	*Laticauda laticaudata*	-	-

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Anguis platura Linnaeus, 1766	*Pelamis platurus*	*Pelamis platurus*	-	-
Thalassophis viperina Schmidt, 1852	*Praescutata viperina*	*Praescutata viperina*	-	-
LEPTOTYPHLOPIDAE				
Glauconia blanfordii Boulenger, 1890	*Leptotyphlops blanfordi*	*Leptotyphlops blanfordii*	-	-
Stenostoma macrorhynchum Jan in: Jan & Sordelli, 1860	*Leptotyphlops macrorhynchus*	*Leptotyphlops macrorhynchus*	-	-
TYPHLOPIDAE				
Eryx braminus Daudin, 1803	*Typhlops braminus*	*Ramphotyphlops braminus*	Robb (1966)	-
Onychocephalus acutus Duméril, Bibron & Duméril, 1844	*Typhlops acutus*	*Rhinotyphlops acutus*	Wallach (1994)	-
Typhlops andamanensis Stoliczka, 1871	*Typhlops andamanensis*	*Typhlops andamanensis*	-	-
Typhlops beddomei Boulenger, 1890	*Typhlops beddomei*	*Typhlops beddomei*	-	-
Typhlops bothriorhynchus Günther, 1864	*Typhlops bothriorhynchus*	*Typhlops bothriorhynchus*	-	-
Typhlops Diardii Schlegel, 1839	*Typhlops diardi diardi*	*Typhlops diardii*	-	-
Typhlops exiguus Jan in: Jan & Sordelli, 1864	-	*Typhlops exiguus*	Not included in Smith (1943)	-
Typhlops jerdoni Boulenger, 1890	*Typhlops jerdoni*	*Typhlops jerdoni*	-	-
Typhlops loveridgei Constable, 1949	-	*Typhlops loveridgei*	-	-
Typhlops meszoelyi Wallach, 1999	-	*Typhlops meszoelyi*	-	-
Typhlops Mülleri Schlegel, 1839	*Typhlops diardi muelleri*	*Typhlops muelleri*	-	-

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Typhlops oatesi Boulenger, 1890	*Typhlops oatesi*	*Typhlops oatesi*	-	-
Typhlops oligolepis Wall, 1909	*Typhlops oligolepis*	*Typhlops oligolepis*	-	-
Typhlops tenuis Günther, 1864	*Typhlops psammeces*	*Typhlops pammeces*	-	*pammeces* is apparently a typographical error for *psammeces*; unjustified emendation by Smith (1943: 48)
Typhlops porrectus Stoliczka, 1871	*Typhlops porrectus*	*Typhlops porrectus*	-	-
Onychocephalus (*Ophthalmidion*) *tenuicollis* Peters, 1864	*Typhlops tenuicollis*	*Typhlops tenuicollis*	-	-
Typhlops thurstoni Boettger, 1890	*Typhlops thurstoni*	*Typhlops thurstoni*	-	-
Typhlops tindalli Smith, 1943	*Typhlops tindalli*	*Typhlops tindalli*	-	-
UROPELTIDAE				
Brachyophidium rhodogaster Wall, 1921	*Teretrurus rhodogaster*	*Brachyophidium rhodogaster*	Gans (1966)	-
Melanophidium bilineatum Beddome, 1870	*Melanophidium bilineatum*	*Melanophidium bilineatum*	-	-
Melanophidium punctatum Beddome, 1871	*Melanophidium punctatum*	*Melanophidium punctatum*	-	-
Plectrurus wynaudensis Beddome, 1863	*Melanophidium wynaudense*	*Melanophidium wynaudensis*	-	-
Platyplectrurus madurensis Beddome, 1877	*Platyplectrurus madurensis*	*Platyplectrurus madurensis*	-	-
Plectrurus? *trilineatus* Beddome, 1867	*Platyplectrurus trilineatus*	*Platyplectrurus trilineatus*	-	-

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Original name	Name in Smith's Fauna	Current name	References	Remarks
Plectrurus aureus Beddome, 1880	*Plectrurus aureus*	*Plectrurus aureus*	-	-
Silybura Canarica Beddome, 1870	*Plectrurus canaricus*	*Plectrurus canaricus*	-	-
Plectrurus güntheri Beddome, 1863	*Plectrurus guentheri*	*Plectrurus guentheri*	-	-
Plectrurus perroteti Duméril, Bibron & Duméril, 1854	*Plectrurus perroteti*	*Plectrurus perroteti*	-	-
Rhinophis fergusonianus Boulenger, 1896	*Rhinophis fergusonianus*	*Rhinophis fergusonianus*	-	-
Typhlops oxyrynchus Schneider, 1801	*Rhinophis oxyrynchus*	*Rhinophis oxyrynchus*	-	-
Rhinophis sanguineus Beddome, 1863	*Rhinophis sanguineus*	*Rhinophis sanguineus*	-	-
Rhinophis travancoricus Boulenger, 1892	*Rhinophis travancoricus*	*Rhinophis travancoricus*	-	-
Plectrurus sanguineus Beddome, 1867	*Teretrurus sanguineus*	*Teretrurus sanguineus*	-	-
Silybura arcticeps Günther, 1875	*Uropeltis arcticeps*	*Uropeltis arcticeps*	-	-
Silybura Beddomii Günther, 1862	*Uropeltis beddomei*	*Uropeltis beddomii*	-	-
Silybura broughami Beddome, 1878	*Uropeltis broughami*	*Uropeltis broughami*	-	-
Uropeltis ceylanicus Cuvier, 1829	*Uropeltis ceylanicus*	*Uropeltis ceylanicus*	-	-
Silybura dindigalensis Beddome, 1877	*Uropeltis dindigalensis*	*Uropeltis dindigalensis*	-	-
Siloboura Ellioti Gray, 1858	*Uropeltis ellioti*	*Uropeltis ellioti*	-	-
Silybura liura Günther, 1875	*Uropeltis liura*	*Uropeltis liura*	-	-

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Sibybura macrolepis Peters, 1861	*Uropeltis macrolepis*	*Uropeltis macrolepis*	-	-
Silybura macrorhyncha Beddome, 1877	*Uropeltis macrorhynchus*	*Uropeltis macrorhynchus*	-	-
Silybura maculata Beddome, 1878	*Uropeltis maculatus*	*Uropeltis maculatus*	-	-
Silybura nilgherriensis var. *myhendræ* Beddome, 1886	*Uropeltis myhendræ*	*Uropeltis myhendrae*	-	-
Silybura nitida Beddome, 1878	*Uropeltis nitidus*	*Uropeltis nitidus*	-	-
Silybura ocellata Beddome, 1863	*Uropeltis ocellatus*	*Uropeltis ocellatus*	-	-
Silybura Petersi Beddome, 1878	*Uropeltis petersi*	*Uropeltis petersi*	-	-
Silybura Phipsonii Mason, 1888	*Uropeltis phipsoni*	*Uropeltis phipsonii*	-	-
Plectrurus Pulneyensis Beddome, 1863	*Uropeltis pulneyensis*	*Uropeltis pulneyensis*	-	-
Silybura rubrolineata Günther, 1875	*Uropeltis rubrolineatus*	*Uropeltis rubrolineatus*	-	-
Silybura rubro-maculata Beddome, 1867	*Uropeltis rubromaculatus*	*Uropeltis rubromaculatus*	-	-
Uropeltis smithi Gans, 1966	*Uropeltis grandis*	*Uropeltis smithi*	Gans (1966)	Replacement name for *Rhinophis grandis* Beddome, 1867
Silybura Wood-Masoni Theobald, 1876	*Uropeltis wood-masoni*	*Uropeltis woodmasoni*	-	-
VIPERIDAE *Coluber Russelii* Shaw & Nodder, 1797	*Vipera russelli*	*Daboia russelii*	Adler *et al.* (2000); Dowling (1993); Hermann *et al.* (1992); Wüster (1998a); Wüster (1998b)	-

Table 1: Synopsis of names of reptile species known from India. Nomenclature in M.A. Smith's *Fauna* compared with that followed at present. For original names, the original orthography has been retained (including upper case first letters for species nomen, accents, etc.) *(contd.)*

Original name	Name in Smith's Fauna	Current name	References	Remarks
Pseudoboa Carinatus Schneider, 1801	*Echis carinatus*	*Echis carinatus*	-	-
Halys himalayanus Günther, 1864	*Ancistrodon himalayanus*	*Gloydius himalayanus*	Hoge and Romano-Hoge (1981)	-
Cophias Hypnale Merrem, 1820	*Ancistrodon hypnale*	*Hypnale hypnale*	Gloyd (1977)	-
Coluber Lebetinus Linnaeus, 1758	*Vipera lebetina*	*Macrovipera lebetina*	Hermann *et al.* (1992)	-
Trimeresurus monticola Günther, 1864	*Trimeresurus monticola*	*Ovophis monticola*	Burger in: Hoge and Romano-Hoge (1981)	-
Trimeresurus jerdonii Günther, 1875	*Trimeresurus jerdoni*	*Protobothrops jerdonii*	Hoge and Romano-Hoge (1983); Kraus *et al.* (1996); Vidal *et al.* (1999); Parkinson (1999)	-
Trigonocephalus mucrosquamatus Cantor, 1839	*Trimeresurus mucrosquamatus*	*Protobothrops mucrosquamatus*	Hoge and Romano-Hoge (1983); Kraus *et al.* (1996); Vidal *et al.* (1999); Parkinson (1999)	-
Trimeresurus strigatus Gray, 1842	*Trimeresurus strigatus*	*Protobothrops strigatus*	Hoge and Romano-Hoge (1983); Kraus *et al.* (1996); Vidal *et al.* (1999); Parkinson (1999)	-
Trimesurus albolabris Gray, 1842	*Trimeresurus albolabris*	*Trimeresurus albolabris*	-	-
Trimeresurus andersoni Theobald, 1868	*Trimeresurus purpureomaculatus andersoni*	*Trimeresurus andersoni*	Malhotra and Thorpe (1996); Wüster *et al.* (1998)	-

Table 1: Synopsis of names of reptile species known from India. Nomenclature in M.A. Smith's *Fauna* compared with that followed at present. For original names, the original orthography has been retained (including upper case first letters for species nomen, accents, etc.) *(contd.)*

Original name	Name in Smith's Fauna	Current name	References	Remarks
Trigonocephalus Cantori Blyth, 1846	*Trimeresurus cantori*	*Trimeresurus cantori*	-	-
Trigonocephalus erythrurus Cantor, 1839	*Trimeresurus erythrurus*	*Trimeresurus erythrurus*	-	-
Coluber Gramineus Shaw, 1802	*Trimeresurus gramineus*	*Trimeresurus gramineus*	-	-
Trimeresurus labialis Steindachner, 1867	*Trimeresurus labialis*	*Trimeresurus labialis*	-	-
Trimeresurus macrolepis Beddome, 1862	*Trimeresurus macrolepis*	*Trimeresurus macrolepis*	-	-
Trigonocephalus (Cophias) malabaricus Jerdon, 1853	*Trimeresurus malabaricus*	*Trimeresurus malabaricus*	-	-
Trimeresurus medoensis Djao in: Djao & Jiang, 1977	-	*Trimeresurus medoensis*		Recorded from India by David *et al.* (2001)
Trimeresurus popeiorum Smith, 1937	*Trimeresurus popeorum*	*Trimeresurus popeiorum*	-	-
Trimeresurus gumprechti David, Vogel, Pauwels & Vidal, 2002	*Trimeresurus stejnegeri*	*Trimeresurus gumprechti*	David *et al.* (2002)	Known from India (P. David, pers. comm. 2003); and northeastern Thailand (David *et al.* 2002)
Trimeresurus yunnanensis Schmidt, 1925	*Trimeresurus stejnegeri*	*Trimeresurus yunnanensis*	Zhao (1995); David and Ineich (1999); David *et al.* (2001)	-
Trimeresurus huttoni Smith, 1949	-	*Tropidolaemus huttoni*	David and Vogel (1997)	-
XENOPELTIDAE				
Xenopeltis unicolor Boie, 1827	*Xenopeltis unicolor*	*Xenopeltis unicolor*	-	-

THE FUTURE

> "*What is the* aim *of knowledge? What is the* purpose *of seeking to understand the natural world?* Why *do we strive continuously to deepen our knowledge of nature?*"
>
> (L. Pyenson and S. Sheets-Pyenson, 1999: 381)
>
> "*It is time to know, because soon it will be too late to learn.*"
>
> (C. Bowden, 1991: 7)

In this era of biodiversity crisis, and especially in the aftermath of the Rio de Janiero Convention on Biodiversity in 1992, the role of natural museums has become one of unusual importance (Alberch 1993, Butler and Macilwain 1998). It is therefore ironic that now, more than at any other time in their history, natural history museums are suffering the real danger of altogether ceasing to exist, or at least, radically changing their roles of promoting biodiversity research and acquisition of knowledge of biodiversity to being mere places of public entertainment. The gradual change seen is the replacement of biological specimen exhibits with interactive displays or screening of films on esoteric scientific topics that do not always accurately reflect the work that a research museum should be doing. A few famous old regional museums in India (such as the Madras Government Museum) as well as in countries of southeast Asia (Sarawak Museum, Kuching and the Raffles Museum, Singapore) have altogether changed focus, to concentrate on ethnography and archaeology.

On paper, several organisations in India would qualify as a systematic institution, in promoting research on biodiversity and associated topics. Ng (2000) listed key attributes of a well-run contemporary natural history museum, which include:

- modern storage facilities for specimens
- well-identified collections
- a professional curatorial staff
- a programme of specimen acquisition
- accessibility of the collection to visitors, especially specialists
- research publications
- library of scientific literature
- database linking the specimens
- networking with other institutions and organisations
- public education policies

The Zoological Survey of India is easily the most important systematic institution in the country, in terms of the size of their collection, including numbers of types, the presence of other historical specimens in its care, the large number of scientists and technical staff hired for biodiversity research and the scientific publications produced by them. Other institutions include the Bombay Natural History Society, and, to a lesser extent, the National Museum of Natural History, New Delhi. There also exists hundreds of universities, colleges, schools and provincial museums spread all over the country that contain zoological collections, comprising specimens acquired through donations by the staff and students, but few would qualify as a systematic institution such as those run with the criteria listed above. Well-run systematic institutions are of great importance, from being institutions to lodge zoological types and other important voucher specimens, to guiding and leading inventories of biodiversity by competent staff of such institutions, and eventually, dissemination of the results in scholarly publications and public education through exhibitions and popular publications. Museums should also be willing to loan specimens to bonafide specialists for identification and study. Surely, no institution in India (or indeed anywhere in the world) has specialists for all groups of organisms, leading to the accumulation of unidentified or erroneously identified specimens, resulting in a poorly known fauna.

Two recently published books showcase the reptile fauna of India — those of Daniel (2002) and Das (2002). Neither are comprehensive, but cover representative taxa, and in many ways, highlight the inadequacy of knowledge of the fauna. Reptiles (and amphibians) in general, receive the short shrift in research funding, despite a review showing that studies of ectothermic vertebrates are framed more conceptually than those on endothermic ones (Bonnet *et al.* 2002).

An important factor that makes it necessary to view the acquisition of knowledge on the systematics of Indian reptiles with great urgency, is the loss of forest cover which is directly linked with threats to her biodiversity, as India struggles to feed and house its over one billion human inhabitants. On the other hand, the science of systematics itself is struggling to stay alive, in the face of growing competition for scant (usually State-funded) resources, and institutions are in search of justifications for their existence. Few countries, far fewer in the Third World, have government-supported systematic institutions (such as India's own Zoological Survey of India). Nonetheless, this once premier organisation, leading systematic research in the zoological sciences, faces the real threat of falling into decay through reduced support and morale, given the vagaries of government priorities (that are moving from supporting basic research to more applied ones, presumably with the hopes of quick economic gains). Several groups of organisms in India have never been monographed, and some recently published works are of dubious quality at best (see review in Das 1999). Systematic collections are international repositories of biodiversity information, yet continue to be treated as old-fashioned houses of public amusement and therefore deemed not deserving of state support. Systematic research in India is also compartmentalised, and kept discrete from ecology, genetics, physiology, behaviour and other branches of the natural sciences. How many times have we been asked, "So, are you a taxonomist or an ecologist?" Certainly, synergy between different subdisciplines in the life sciences would benefit all (see, for instance, Brooke *et al.* 1995, Harvey and Purvis 1991). In an address to the Flora Malesiana Symposium, Stevens (1989) wryly commented that while taxonomic intuition is of great importance, an understanding of function and ecology is also central to classification. Indeed, globally, many natural history museums themselves have unfortunately moved away from basic scientific research, and specimen acquisition, cataloguing and display, to trying to answer other 'Big Questions.' Attempts to make taxonomy more 'relevant' to the rest of biology, as though taxonomy has no right to exist as a separate discipline, have weakened the rest of biology as a whole (Erzinçlioglu 1993). A few museums have such an excess of administrators that the basic work of specimen identification cannot be done!

Another major aspect potential researchers have to deal with is collection and export permits. Collection of biological specimens, and their subsequent export, are now regulated by a variety of governmental agencies, and valid permits for undertaking collecting activities in nearly every country in the world are now mandatory (see, for instance, Duellman 1999). Within India, the Indian Wildlife (Protection) Act of 1972 provides the legal basis for the protection of wild species of flora and fauna. This Act has seen several emendments, and lists a large number of herpetological taxa. Legislation also exists to monitor movement of biological specimens across boundaries (e.g. the Convention in International Trade in Endangered Species in Wild Fauna and Flora, acronym: CITES) and even importation into a second country (e.g. the U.S. Endangered Species Listing). Knowledge of local, regional and international laws is therefore critical before any collection activities can be conducted. Nonetheless, state institutions regulating funding continue to exert considerable influence on not only the type of research that should be done, sometimes based not on scientific but other criteria, including nationalism, professional jealousy and zealous protection of resources considered 'theirs.' Denial of access to biological resources to people who understand them the most (i.e. the systematists and ecologists) also stems from the confusion of environmental conservation with animal welfare, in addition to emotions associated with the removal and euthanasia of wild species. Stuebing (1998) likened sampling of species to a biopsy: true it hurts. But knowledge thereby acquired has the potential to save ecosystems and populations, both surely desirable by society.

Centuries ago, our own species began one of the greatest scientific journeys ever conceived — the exploration of life on Earth (see Wheeler 1995). The benefits of these voyages to the then unknown ends of the earth to humans have been tangible, leading to the discovery of new continents, of new people, of new mineral and plant and animal produce, of medicines, fuel, timber, textiles and spices. Wild species and wilderness areas have also inspired songs, poetry, dances, stories, myths, handicrafts, cuisine, decorations, tattoos, rituals, to name but a few aspects of life. Nearly two million species of microbe, protist, plant and animal species have been described. But the task isn't done yet.

Wrote Thomas Malthus (1766-1834) of the need to have the government, and indeed everybody else, to leave science alone:

"*If science be manifestly incomplete, and yet of the highest importance, it would surely be most unwise to restrain inquiry, conducted on just principles, even when the immediate practical utility of it was not visible. In mathematics, chemistry, and every branch of natural philosophy, how many are the inquiries necessary for their improvement and completion, which, taken separately, do not appear to lead to any specifically advantageous purpose; how many useful inventions, and how much valuable and improving knowledge would have been lost, if a rational curiosity and a love of information had not generally been allowed to be a sufficient motive for the search after truth.*"

(extracted from Asma, 2001: 81)

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Appendix: Glossary of terms used in systematics, taxonomy, nomenclature and biogeography

affinity - relationship.

allopatric - pertaining to species or populations that occupy mutually exclusive geographic areas.

apomorphic - a relatively more derived state in an evolutionary sequence of homologous characters.

autapomorphy - pertaining to apomorphic characters found in only one or two sister groups.

binomen - scientific designation of a species, consisting of a generic and specific names.

biogeography - study of geographic distribution of organisms.

character - structure or behaviour of an organism that may provide evidence of relationship.

clade - species of a phyletic lineage derived from a single stem species.

cladistics/cladism - theory by which organisms are ordered and ranked exclusively on joint descent from a single ancestral species.

congeneric - pertaining to species belonging to the same genus.

conspecific - pertaining to populations of the same species.

derived character - character that differs from the ancestral condition.

Appendix: Glossary of terms used in systematics, taxonomy, nomenclature and biogeography (*contd.*)

diagnosis - formal statement of characters that distinguish a taxon from its close relatives.

disjunction - major geographical gap in distribution of a taxon.

emendation - an intentional modification of spelling of a taxon name.

endemic - restricted to a particular region.

holotype - a single specimen designated or indicated as the type by the original author at the time of first description of the taxon.

hypodigm - the entire material of a taxon available to a taxonomist.

identification - determination of the taxonomic identity of a biological specimen.

lectotype - one example from the original series of syntypes that was subsequently selected to serve as the type.

lineage - descendant taxa of a common ancestor through time.

monophyly (n)/*monophyletic* (adj).- taxonomic group whose members share the same ancestor.

monotypic - higher taxon consisting of a single lower taxon.

neotype - specimen selected as type subsequent to original description when the original types are destroyed or suppressed by the International Commission of Zoological Nomenclature.

nomenclature - a system of names, and also, all rules guiding the use of these names.

parapatry - non-overlapping geographical distribution of populations.

paraphyly (n) / *paraphyletic* (adj).- taxonomic group containing taxa which do not share a common ancestor.

paratype - specimen other than the holotype that was used by the original describer and was thus designated.

phylogeny - hypothesis of relationship of evolutionary relationships of organisms.

Pleistocene refugia - favourable (here, warm) areas where species survived periods of glaciation.

relict - localised remnant of a previously wider distribution pattern.

sympatry - co-occurrence of two or more populations within the same geographic area.

synapomorphic - pertaining to a uniquely derived apomorphic character found in two or more taxa under study.

synonym - a chronological list of scientific names, together with their authors and dates of publication, that are associated with a taxa.

syntype - two or more types indicated as being in the type series by the original author at the time of description.

systematics - "the science dealing with the diversity of organisms" (Mayr and Ashlock, 1991: 431).

taxonomy - the theory and practice of classifying organisms.

type - zoological/botanical object/specimen that serves as the basis for the name of a taxon.

type locality - locality at which the type series was collected.

vicariance - fragmentation of ancestral species through the formation of a physical or ecological barrier.

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HISTORY AND DEVELOPMENT OF FISHERIES RESEARCH IN INDIA

E.G. SILAS[1]

Key words: Fisheries research, marine surveys, State Fisheries Departments, Fisheries Research Institutes of India

Fishing in the earlier half of the last century mainly comprised artisanal inshore capture fishery using sailboats and catamarans, and culture of Bengal carps (catla, rohu and mrigal). The Indian Fisheries Act of 1857 defined the powers and responsibilities of the erstwhile presidencies and princely states. Immediately after India's independence, for a few decades, the erstwhile Madras and Bombay States led the country in fisheries surveys and research activities. With I.A.S. officers at the helm of state fisheries departments, these aspects have been relegated to the background and replaced by central governmental agencies.

Precursors of today's multitude of research organisations were the CMFRI and CIFRI (for the full names of these acronyms, please see the body of the article), established just a few months prior to the country's independence. With the proliferation of fishery activities and research, these parent institutions were split, in 1987, into CICFRI, CIFA, CIFE, CIBA, CIFT, NRCCWF and NBFGR. CMFRI studies the fishery biology of commercially important fish and shellfish (both molluscan and crustacean), while the Fishery Survey of India (FSI) is concerned with offshore fishery surveys. The original culture of Bengal carps has now diversified to aquaculture of other carps, high altitude coldwater fishes, edible and pearl oysters and mussels, prawns, crabs and lobsters, and their associated diseases and parasites.

INTRODUCTION

> "*With timely action, fisheries can continue to provide food, jobs and enjoyment for millions of people worldwide. But ultimately this means changing our focus from what is done to a fish to what can be done for the fish. And the time for that change is now.*"
>
> (Anne Platt McGinn, 1998)

The world's oceans were for long considered to have limitless fishery resources freely open to all for exploitation. The conflicts of fishers over open access and exclusive rights have intensified in the past fifty years. Worldwide, many of the major fish stocks have declined, reaching critical levels or have collapsed as was the case with the once thriving whaling industry prior to World War II. Now we know that the living aquatic resources, while renewable, are not infinite, and need good management for maintaining sustainable yields. Today, with depletion of many stocks, rising tensions prevail among fishers who are loaded with excess capacity in fishing crafts and gears. All this, despite the United Nations Law of the Sea Convention (UNCLOS) of 1982, which was ratified in 1984, granting rights to Coastal States to have an extended jurisdiction over their Exclusive Economic Zone (EEZ) of 200 nautical miles from the coast for developing their fisheries. From the traditional 12 nautical miles of territorial waters along the coast by Bay Islands, India today has 2.02×10^6 sq. km sea area, comprising 0.86×10^6 sq. km on the west coast (including the Lakshadweep Sea), 0.56×10^6 sq. km on the east coast and 0.60×10^6 sq. km around the Andaman and Nicobar Islands.

For those interested in the wealth of our knowledge about the fish and fisheries dating from the pre-Vedic, Vedic and post-Vedic periods, the period of the Sangam literature of south India, the works of Kautilya (ARTHASHASTRA) and King Someswara (MANASOLLOASA) and the Mughal period, reference is invited to Hora (1952), Raj (1955), Rao (1957) and Chitranshi (2000).

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FOUNDATION OF FISHERIES RESEARCH IN INDIA

Carolus Linnaeus to Francis Day

The foundation for fisheries research in India was laid by some of the early naturalists, zoologists and botanists who either worked in the Museums of Natural History in England and in European countries, where dried or preserved material from the east, including India, was received, identified, catalogued and reported on. From the times of Carolus Linnaeus, founder of the modern classification for plants and animals, there have been a number of taxonomists who have studied fishes, crustaceans and other aquatic organisms from India which earlier included Pakistan, Bangladesh, Burma and Sri Lanka (Ceylon), and from the coastal waters. Notable ichthyologists among them were Cuvier, Valenciennes, Lacepede, Bloch, Schneider, Forsskäl, Bleeker and Albert Gunther. Among early carcinologists were Fabricius, H. Milne Edwards and de Man. They have described several fishes and crustaceans new to science, many of which are of commercial importance today.

There were also naturalists with different avocations in India, who collected and described fishes, other aquatic animals and plants and made observations on bionomics. Notable among those who had contributed to our knowledge are Patrick Russell, Hamilton-Buchanan, Edward Blyth, Stolizka, Sykes, J. McClelland and T.C. Jerdon. The most outstanding contribution was that of Dr. Sir Francis Day, a veterinary surgeon and naturalist who travelled extensively in India in the mid-nineteenth century and wrote several scientific papers and monographs such as the FISHES OF MALABAR (1865). Day's *magnum opus* THE FISHES OF INDIA in two volumes (1875-78) followed by FISHES in the 'Fauna of British India' Series in two volumes (1889) describing 1,418 species are the two most indispensable works on Indian fish taxonomy to date. Day's interests were catholic and, besides his works on ichthyology, his most important contribution was a book entitled THE LAND OF THE PERUMALS. Day was knighted and he was appointed the Inspector General of Fisheries of India and Burma. Recently an excellent book on the life and works of Francis Day by Dennis Tucker and K.C. Jayaram, was published by the British Museum of Natural History.

Indian Fisheries Act - 1897

A milestone in the history of Indian fisheries is the enactment of the Indian Fisheries Act of 1897. The Act delegated to the erstwhile Provinces (States) the responsibility of development and conservation of fisheries in the inland and the territorial waters of the respective States. It also empowers the States to formulate their own rules and regulations for the protection and safeguard of their fisheries. Further, the Act provided adoption of conservation measures to prevent the destruction of resources. As a consequence, the development, management and conservation of fish and fisheries became a State subject.

The last 106 years have witnessed a sea change in fisheries research, education, extension and development, and there is an imperative need for promulgating a new Fisheries Act.

Early marine surveys

The *H.M.S. Challenger* Expedition in the late sixties and seventies of the 19th century triggered interest in marine resource surveys in the Indian seas. This was followed by the *R.I.M.S.S. Investigator* which carried out coastal and deep-water surveys in the Bay of Bengal and the Andaman Sea. These resource surveys brought to light many new and interesting fauna. James Wood-Mason published a series of papers on deep-sea crustaceans, especially from the Andaman Sea. The Navy also had Surgeon Naturalists working on board the *Investigator*, and among these the works of Alfred Alcock, Lloyd and Lt. Col. R.B. Seymour Sewell are most invaluable. Alcock's book A NATURALIST IN INDIAN

SEAS (1902) is a very interesting narrative of the many discoveries made during his voyages. Sewell was an authority on marine Copepoda. Later, when the Zoological Survey of India was founded in 1908, Sewell joined the Survey and his work on the hydrology and plankton of the Rhamba Bay, published in the *Memoirs of the Indian Museum* as part of the Survey of the Chilka lake, is an outstanding piece of work.

Role of the Zoological Survey of India in fisheries research

The Zoological Survey of India from its inception functioned as the Centre for research on fish, fisheries and marine biology. It was the national repository for terrestrial and aquatic organisms collected from the Indian region. This was made possible by its eminent Directors, namely Nelson Annandale who initiated studies on the hydrology of upland lakes, and coastal lagoons and lakes; Stanley Kemp who, in 1924, led the British Antarctic Expedition; R.B. Seymour Sewell whose forte was marine biology and oceanography; Baini Prashad, an authority on Indian molluscs and fisheries, and Sunder Lal Hora, an ichthyologist *par excellence*, ecologist and fish taxonomist. It is their leadership and research output that kept the Zoological Survey of India in a pre-eminent position among research institutions in India until the mid-1950s. Each one of them in their own right contributed to the early development of fish and fisheries research in India.

Annandale felt that the focus of research at ZSI should not be confined to only pickled specimens, but extend to observations in the field on the ecology and life habits of species as well. This dictum was carried out to the maximum by Sunder Lal Hora whose work on hill stream fishes published in the *Transactions of the Royal Society of Edinburgh* is a classic piece of work which has given us an in-depth understanding of an ecosystem that is gaining in importance today. Hora propounded the "Satpura Hypothesis" which led to a considerable amount of work on animal and plant species diversity. His contribution to ichthyology, ecology and biology of freshwater fishes has enriched our knowledge. Hora's interest in fisheries research led him to head the Department of Fisheries of West Bengal for some time and also play an important role in the founding of the Central Inland Fisheries Research Station at Barrackpore, Calcutta (=Kolkata). His researches on fish, especially the "wandering of the Bombay duck", on *Hilsa* and several others, helped in understanding more of the ecology and species diversity of the Gangetic estuarine system. He was a source of great encouragement to many. Those who worked with him, such as T.V.R. Pillay, E.G. Silas, A.G.K. Menon and K.C. Jayaram, subsequently headed research management positions in both national and international organisations, thereby influencing the development of fisheries research in its different facets.

Role of State Fisheries Departments in promoting fisheries research

It was Sir Frederick Nicholson who established the Department of Fisheries, in the erstwhile Madras Presidency, and a fish preserving unit for improving the keeping quality of fish. He also recommended the establishment of fisheries research centres. Madras Presidency had also a very distinguished scientist in James Hornell who initiated research in the coastal waters of the Presidency, especially in the Gulf of Mannar and along the southwest coast, as the Presidency extended along the west coast up to Goa. His works on the chank and pearl oyster fisheries and the monograph on Kathiawar are outstanding contributions. Marine surveys were conducted in the coastal waters along Malabar coast and the Lakshadweep Islands. James Hornell, in 1917, reported on the widespread mortality of fishes along the Malabar coast caused by a "Euglenid or Flagellate B, or an Infusorian Protozoa +". It was through the research of R. Subrahmanyan, one of India's leading phytoplanktologists, that in 1954 the causative organism for such recurring fish mortalities was identified to belong to Chloromonadineae, and the flagellate was named in honour of Hornell as *Hornellia marina* gen. *et* sp. nov. Hornell laid a sound foundation for fisheries research in the Department.

The Madras Presidency played an important role in Human Resource Development (HRD) for fisheries research and management in the early years, as many of its scientists went on to head State Fisheries Departments, National Fisheries Research and Development Institutions or hold responsible positions in the Department itself. The *Madras Fisheries Bulletin* of yesteryear documented the research conducted in the Presidency's rivers, lakes and reservoirs and the coastal waters, especially in the Gulf of Mannar where a lot of effort was expended in the chank and pearl oyster fisheries.

Other states too had Departments of Fisheries carrying out both research and development activities. Dr. S.B. Setna, rightly known as the "Father of mechanisation" of fishing boats in India, pioneered research and development programmes in the erstwhile Bombay State/Presidency comprising present-day Gujarat (excluding the erstwhile Saurashtra State), Maharashtra and North Kanara districts, which were ably carried on by C.V. Kulkarni, and A.G. Kalawar. Kulkarni's contributions include his studies on the breeding of *Hilsa ilisha* in the Narmada estuary, and the description of a unique new Cyprinodont fish *Horaichthys setnai* gen. *et* sp. nov. The establishment of the Taraporevala Aquarium and Taraporevāla Marine Biological Station, closely linked to the Fisheries Department, facilitated research activities on ornamental fishes and live feeds by scientists such as H.G. Kewalramani, B.F. Chhapgar, K.N. Sankolli and others.

Gujarat, including erstwhile Saurashtra, with S.T. Moses, C.B. Srivatsa and K. Chidambaram heading the Fisheries Department, witnessed a rapid development in its marine sector. Today, Veraval fishing port in Gujarat accounts for the maximum number of fish landings in India. T.V.R. Pillai, who published his account "The Fishes of Kodinar" in the *Journal of the Bombay Natural History Society*, left Gujarat and went on to Calcutta where he spent a few years with the Central Inland Fisheries Research Institute before joining the FAO. Pillai carried out outstanding research on racial studies of *Hilsa ilisha* and *Puntius sarana*, which are yet to be emulated.

Karnataka, in the early years, grouped fisheries under the Animal Husbandry Department, but it had dedicated scientists such as B.S. Bhimachar, A. David and H.D.S. Iyengar, who contributed much to the understanding of reservoir and riverine fisheries, identifying natural spawning grounds, and research on the advantages of integrated aquaculture of paddy-cum-fish.

The Department of Fisheries of Bengal, Bihar and Orissa was a linked unit. T. Southwell, who headed Bengal Fisheries, established the fisheries laboratory in the Indian Museum, Calcutta. A series of scientific publications came from this laboratory, some jointly by Southwell and Baini Prashad. The latter became the first Fisheries Development Adviser to the Government of India, Ministry of Food and Agriculture.

When Orissa got its own Department of Fisheries, it was G.N. Mitra's catholic interests that moulded it, and carried it on with researches on marine capture fisheries, Chilka lake fisheries, population dynamics and aquaculture engineering, the last being his obsession. Eventually, he became the Fisheries Development Adviser to the Government of India, and stimulated innovative research programmes in the Fisheries Research Institutes under the Ministry of Agriculture.

In Madhya Pradesh, bund breeding of carps and research on reservoir fisheries were initiated by G.B. Dubey. Some of the other states, in spite of having Fisheries Departments, did not have any viable research component, devoting all energy to developmental and welfare programmes. Some states had Fish Wardens who also helped in the conservation of stream ecology and game fishes such as the mahseer. Although individual initiative in fisheries research was there in some of the states, with the passage of time this was no longer a priority, especially as technocrats lost ground to bureaucrats from the Indian Administrative Service. Added to this, with the establishment of the State Agricultural Universities (SAUs) after the 1960s, the research activities and responsibilities from the State Departments of Fisheries were transferred to the SAUs.

Action for the Establishment of Fisheries Research Institutions

Dr. Baini Prashad, the Director of the Zoological Survey of India in 1943, stressed the need for the establishment of fisheries institutions in India in a Memorandum entitled "Post-War Development of Indian Fisheries". He became Fisheries Development Adviser to the Government of India in 1944. His recommendation as Member Secretary, in the "Report of the Fish Sub-Committee of Policy No. 5 on Agriculture, Forestry and Fisheries" dated January 18, 1945, for the creation of research institutes in fisheries was referred by the Government to Lt. Col. R.B. Seymour Sewell, under whose advice the Central Marine Fisheries Research Station (presently known as the Central Marine Fisheries Research Institute or CMFRI) was established on February 3, 1947 in the Zoology Department of Madras University, and subsequently shifted in 1949 to Mandapam Camp, Tamil Nadu, and in 1972 to Cochin, Kerala. On March 17, 1947, the Central Inland Fisheries Research Station, renamed Central Inland Fisheries Research Institute (CIFRI) was established at Barrackpore, West Bengal. The Central Fisheries Technology Research Station was started at Cochin in December, 1957 and in the following year a processing wing was added to it for dealing with research on handling, preservation, processing, product development and quality control. In 1961, the Centre was elevated to the status of an Institute as the Central Institute of Fisheries Technology (CIFT). The Central Institute of Fisheries Education (CIFE) was established in 1961 at Versova, Mumbai and was elevated to the status of a Deemed University on March 29, 1989. CMFRI, CIFRI and CIFT were transferred in August 1967, and CIFE on April 1, 1979, from the Ministry of Agriculture to the Indian Council of Agricultural Research.

Fisheries research organisational linkages

A number of Ministries and Departments in the Government of India support fisheries research. The Department of Animal Husbandry, Dairying and Fisheries under the Ministry of Agriculture (MOA) has the following research-cum-development, training and extension institutes: the Fishery Survey of India (FSI, earlier known as Deep Sea Fishing Station) which has seagoing facilities and helps in fish stock assessment research, the Central Institute of Fisheries Nautical and Engineering Training (CIFNET), and the Integrated Fisheries Project (IFP) (the erstwhile Indo-Norwegian Project). The seagoing facilities of these Institutions have also been utilised by the ICAR Fisheries Research Institutions for conducting research programmes.

The Ministry of Commerce has under it a statutory body, the Marine Products Export Development Authority, which also funds research programmes in aquaculture and post-harvest technologies. The Authority has its own research wing.

The Central Salt and Marine Chemicals Research Institute (CSMCRI), jointly with the CMFRI, has conducted seaweed surveys and analysed their biochemical constituents, studied the industrial uses of seaweeds, and conducted trials in seaweed farming using different techniques. The NIO, CMFRI, and the National Drug Research Institute (NDRI), Lucknow, have been working on isolating bioactive compounds from marine organisms in the programme "Drugs from the Sea." The Central Food Technology Research Institute (CFTRI), Mysore is the nodal institute for food technology and has, on its own and in conjunction with CIFT, Cochin, developed food products and quality standards.

FAO/UNDP Pelagic Fisheries Project (PFP)

This internationally aided programme was aimed at estimating mainly the pelagic fishery resources along the neritic and oceanic waters using pelagic fishing gear and acoustics from the FAO Research Vessel *Rastrelliger*, an all-weather boat. The Project also had a smaller vessel *R.V. Sardinella* for work in shallower coastal waters, but well equipped with acoustic instruments. A considerable amount of research went into standardising acoustic procedures. This was the first time in the tropical seas that such an innovative acoustic survey programme to estimate fish stocks and fishery resources was attempted.

FAO/UNDP Bay of Bengal Programme

Prior to the 1970s, the concept of social scientists, anthropologists and economists being associated with fisheries research was alien in the Indian set-up. The Bay of Bengal Programme helped reorient our thinking. The project has thrown wide open, subject areas where sociologists and economists could investigate problems, develop models, indicate options for development programmes and conduct malady-remedy analysis.

Reorganisation of the Fisheries Research Institutes under the Indian Council Of Agricultural Research

In the name of strengthening and streamlining research, education, extension and training activities of the fisheries institutes under ICAR, a major reorganisation was undertaken in 1987. In this process, the erstwhile institutes were realigned and the following institutes were set up:

1. Central Marine Fisheries Research Institute (CMFRI); Headquarters (HQ) at Cochin with 12 Regional and Research Centres and 28 Survey Centres.
2. Central Institute of Fisheries Technology (CIFT); HQ at Cochin with five Research Stations.
3. Central Inland Capture Fisheries Research Institute (CICFRI); HQ at Barrackpore (a part of the original CIFRI) with 11 Research Centres and 6 Survey Centres.
4. Central Institute of Freshwater Aquaculture (CIFA); HQ at Bhubaneswar (a part of the original CIFRI) established on April 1, 1987, with 6 Research Centres and 11 Field Centres.
5. Central Institute of Brackishwater Aquaculture (CIBA); HQ at Chennai (a part of the original CIFRI) established in November, 1985, with 3 Research Centres and 1 Field Centre.
6. National Research Centre for Cold Water Fisheries (NRCCWF); HQ at Bhimtal (part of the original CIFRI) established in 1988, with 2 Field Centres.
7. National Bureau of Fish Genetic Resources (NBFGR); HQ at Lucknow established in December, 1983.
8. Central Institute of Fisheries Education (CIFE); HQ at Mumbai, given the Deemed University status on March 29, 1989, with 5 Research Centres.

ROLE OF ICAR FISHERIES INSTITUTES IN THE GROWTH OF FISHERIES RESEARCH

A. Freshwater Fisheries and Aquaculture

For the past half a century, the ICAR fisheries institutes have been playing a dominant role in fundamental and applied research in fisheries in the freshwater, coastal brackishwater and marine sectors, both in capture fisheries and in aquaculture/mariculture. We shall look at these developments in a sequential order.

I. RIVERINE FISHERIES

Riverine fishery has been, and still is, mainly an artisanal level activity. In the early years, research was directed towards surveys to understand resource distribution, physical and ecological features, hydrology of rivers, plankton, benthic biomass and nutrient load, and pre-impoundment surveys. Natural spawning grounds, estimation of spawn availability and breeding migrations were studied, so also resource availability in relation to zonation. An important achievement was the breeding and rearing of *Hilsa ilisha* at Allahabad. Research today is oriented towards anthropogenic pressures, pollution and engineering works that adversely affect the ecosystems and endanger indigenous fish and other aquatic organisms. The protection of wild stock to prevent genetic drift in farm-reared fish, the conservation of river habitats and biodiversity, the protection of endangered riverine fauna such as the river dolphin *Platanista gangetica*, the gharial *Gavialis gangeticus* and fishes such as the mahseer (*Tor* spp.) and *Neolissocheilus hexagonolepis*, and the development of management measures through scientific inputs are ongoing. The technology and scientific know-how to restore natural populations through ranching, habitat improvements and adoption of management strategies are available with the Institutes (CICFRI, NRCCWF), but need to be implemented at the State level.

II. RESERVOIR FISHERIES

In 1995, VV. Sugunan classified and gave the State-wise distribution of large irrigation tanks, small, medium, and large reservoirs in India, altogether 19,370 in number and covering a waterspread area of 3,153,366 ha. All are man-made and combine the fluviatile and lacustrine systems.

III. UPLAND COLD WATER FISHERIES

The works of Sunder Lal Hora, E.G. Silas, A.G.K. Menon and K.S. Misra added much to our knowledge of the ichthyofauna of the upland cold water rivers and lakes. The ecology and hydrological conditions of a number of natural lakes in the Kumaon Himalayas were studied. Under the UNESCO sponsored "Man and Biosphere Programme," the limnology of the Loktak Lake, Manipur was studied. Research has been done in induced breeding of different species of snow trout (species of *Schizothoraichthys* and *Schizothorax*) from wild stock for ranching in the streams. Besides successfully breeding the golden mahseer *Tor putitora* and pond-rearing it in Bhimtal, the new Centre (NRCCWF) has also developed composite fish culture suitable for the hill regions with the following combination, namely *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *Ctenopharyangodon idella.*

The breeding and propagation of the mahseer was a successful programme at the Tata Electric Company's Wulvhan Lake facility at Lonavala, Maharashtra.

IV. FRESHWATER AQUACULTURE

The progress from spawn collection from natural spawning grounds by stripping, to induced breeding of Indian major carps (IMC), other carps, catfishes and other fish species, was a giant step forward. In 1955, H. Chaudhuri successfully spawned the minnow *Esomus danricus* by pituitary injection. By 1957, carps such as *Labeo rohita*, *L. bata*, *Cirrhinus mrigala*, *C. reba* and *Puntius sarana* could be induce-bred. This was a major breakthrough which gave a fillip to freshwater aquaculture. Subsequently, research has kept pace with developmental needs, and great strides have been made in the hormonal physiology of fish and shellfish so that a wide range of species could be induced to breed, some even months before the normal breeding season.

It must be added that during the 1970s and '80s, with scarcity of carp pituitary extracts, research was directed towards the use of human chorionic gonadotropin (HCG) for fish breeding; isolation, characterisation and purification of fish gonadotropin (GtH) and its use in fish breeding; use of mammalian gonadotropin releasing hormone for fish breeding and use of fish gonadotropin releasing hormone (GnRH). Today, Ovaprim® prepared from salmon gonadotropin releasing hormone and domperidone are widely in use, with dosages standardised for induced breeding of carps and catfishes. The importance of Ovaprim® which has given a boost to aquaculture will be evident from the logarithmic proportions in which fish seed production has increased from only 490 million fish fry in 1973-74 to over 20,000 million fry today.

Research has been underway in the use of pheromones in fish reproductive physiology. It has been shown that waterborne steroids and steroid glucuronids originating from the reproductive organs act as pheromones in many species of fishes. Exposure of spawners to the ovarian fluids induces ovulation and gonadotropin release, increasing plasma gonadotropin (GtH) in the catfish *Clarias batrachus*.

In an All-India Coordinated Research Project on air-breathing fish culture, techniques were developed for the maturation and breeding of air-breathing catfish, and their nutritional requirements were studied in order to successfully culture them. Research on sewage-fed water bodies holding fish demonstrated the recycling of organic waste as well as their treatment and further utilisation for agricultural purposes. Research was also carried out on a variety of diseases that afflicted Indian carps and on the prevention and control of fish parasites.

Another important area of research in freshwater aquaculture was composite fish culture, i.e. the culture of compatible combinations of Indian and Chinese carps. Research on composite fish culture has yielded excellent results; from the traditional culture methods producing about 600 kg/ha/year, it has been possible to exceed 10 t/ha/year. Some fish farmers in Eluru, Andhra Pradesh have achieved production of 13 to 15 tons and more, per hectare per year. The research and development at the Balabhadrapuram experimental fish farm of CIFE was so supportive as to result in an explosive growth of freshwater fish culture, from nothing to over 100,000 t, in the Kolleru wetlands in the late 1980s.

For increasing productivity and better economic returns, research was initiated on integrated fish-farming involving crop-livestock-fish-prawns in various combinations. The operations, though highly location-specific, yielded good economic returns. Polyculture of combinations of carps and non-carp species also showed high yields and good economic returns.

One of the recent developments has been the production of pearls from the freshwater mussels *Lamellidens marginalis, L. corrianus* and *Parreysia corrugata*, using gonadal implantation of nucleus for spherical pearls. Research on culturing of pearl nacre-secreting mantle epithelial cells under *in vitro* conditions has been successful, enabling production of uniform quality of pearls. Research aimed at post-harvest value addition as well as mussel spat production for the grow-out system is also being done. In view of the importance of this research, and the need for further refinement to meet international standards, ICAR has established the Centre of Excellence in Pearl Culture at CIFA.

RESEARCH ON FISH GENETICS

India is one of the few countries that have taken a lead in research on fish and shellfish genetics. Until the early 1970s, fish culture remained largely empirical and artisanal. Then onwards, research in fish genetics started receiving greater attention for the purposes of upgrading the quality of cultivated species like

Indian major carps for enhanced productivity, and the conservation and management of genetic diversity in natural stocks. The National Bureau of Fish Genetic Resources (NBFGR), Lucknow, was established to focus on fish genetic resources of the country, their collection, classification, evaluation and cataloguing; conservation and protection of endangered aquatic species and to monitor introduction of exotic species.

I. Research on Stock Identification

NBFGR has been actively involved in the cytogenetic analysis of Indian major carps, exotic carps, mahseers, freshwater catfishes, snakeheads (*Channa* spp.) and the endemic species of the Western Ghats, developing species-specific banding profiles and characterising the genetic stocks. In 1998, NBFGR brought out a chromosome atlas of karyotypes of 128 species of teleosts from Indian waters. Three schools of research, one at CIFE, Mumbai, the second at the Department of Zoology, Kurukshetra University, Kurukshetra, and the third at the University of Kalyani, West Bengal, have been actively carrying on research on chromosome banding techniques in many freshwater teleosts which has been helpful in detecting polymorphism in Indian species at inter-specific and inter-generic levels.

II. Biochemical and Molecular Genetics

At NBFGR, different stocks of *Catla catla* and *Labeo rohita* from different rivers of the Gangetic plains and northeast India have been identified using molecular and allozyme markers. H.K. Lal found the anadromous hilsa (*Tenualosa ilisha*) population in the River Ganga, above and below Farakka Barrage, and the Brahmaputra not exhibiting significant genetic heterogeneity. Use of allozymes and DNA markers has helped to find that the butterfish *Lactarius lactarius* from the east and west coasts of India were distinct stocks, as also the highly endemic yellow catfish *Horabagrus brachysoma* from Chalakkudy and Meenachil rivers, Kerala. Genetic markers for the marine catfish *Tachysurus* in which taxonomic ambiguity exists have been identified. Studies using allozymes and RAPD markers have shown that the stocks of shrimps *Penaeus indicus* and *P. monodon* along the east and west coasts of India were distinct. Nuclear fingerprinting in Indian major carps and tilapia has been done with a view to develop species-specific patterns and to differentiate between individuals within a population.

III. Techniques for Enhancing Aquaculture Productivity

a. Sex control

Monosex culture of fish has the advantage of growing one sex with faster growth rate and good meat quality. So also, production of sterile populations is economic in fish farming as there is no energy loss in gonadal maturation, which otherwise may utilise about 20% of the food energy. Research is on for the application of either androgen or oestrogen to juveniles to override the intrinsic sex-determining mechanism and direct it to either male or female sex or induce sterility without altering the genotype. At the Madurai Kamaraj University (MKU), Madurai, 100% masculinisation and feminisation were achieved in tilapia (*Oreochromis mossambica*), *Betta splendens*, *Poecila reticulata* and *Brachydanio rerio* by administration of steroids.

b. Chromosomal manipulation

Chromosome sets can be manipulated in externally fertilising fishes to produce gynogenetic, androgenetic and polyploid individuals.

1. Gynogenesis: The various applications of gynogenesis are chromosomal mapping, inbreeding with homozygosity, and generation of monosex populations. Gynogenesis has been induced in Indian major carps *Labeo rohita, Cirrhinus mrigala* and *Catla catla* by using cold shocks (12° C for 10 minutes) or heat shocks (39° C for 1 minute). Gynogenetic specimens of silver carp have also been produced. Production of gynogenetic zebra fish (*Betta splendens*) and tilapia, and of YY supermale tilapia by gynogenesis and sex reversal have been carried out at MKU, Madurai.

2. Androgenesis: Androgenesis can be induced by the destruction of female nuclear genome before fertilisation using UV rays and fertilising it with normal sperm, whereby only the paternal genome is contributed to the offspring. This is useful in producing inbred lines. In conjunction with sperm cryopreservation, androgenesis may prove useful in conservation programmes where females of a species are not available. Survival of androgenic individuals is much lower compared to gynogens, as the cellular organelle of the egg is affected during irradiation. Putative androgenic common carp has been produced in NBFGR but further improvement and upgrading of teleost androgenic production is yet to be done.

3. Polyploidy: By chromosomal stimulation it is possible to obtain haploid, triploid and tetraploid fishes. These fishes are likely to be sterile, and since the process of gametogenesis is avoided, they can grow faster. Direct induction of triploidy has been done in the common carp and grass carp. Triploids can be produced by suppression of meiotic metaphase II by subjecting the egg to a pressure or temperature shock shortly after fertilisation. Triploid rohu has been produced at CIFA, and *Heteropneustes fossilis* at Benaras Hindu University, Varanasi. MKU, Madurai has produced triploid tilapia and introduced tetraploidy in *Betta splendens*, *Brachydanio rerio* and *Poecilia reticulata.*

c. Hybridisation

Selective breeding, multiple breeding and hybridisation are spin-offs from the induced breeding technology developed at CIFRI, Cuttack in the mid-1950s. So far about 44 intergeneric and interspecific hybrids have been produced in India, many of which are fertile, but most hybrids have not performed well with regard to desired economic traits. Only one combination, namely rohu female x catla male, which combines the small head and the meat quality of rohu with the fast growth of catla has found favour among fish farmers and consumers. Locally called 'naadan', it is produced in hatcheries in West Bengal, and Andhra Pradesh. Reciprocal hybrids of *Heteropneustes fossilis* and *Clarias batrachus*, and *H. fossilis* and *H. microps* have also been produced.

Hormonal advancement of maturation and multiple breeding of Indian major carps has become possible through the application of non-steroid hormones such as HCG, LHRH-a and PGE.

d. Selection

The success of selection depends on the additive genetic variation in the selected population. Heritability estimates of the traits selected are essential for fish breeders to assess the response to the selection programme and the time and cost required to reach the desired goal. A 5% predicted response was obtained in one generation selection of *Etroplus suratensis.* Selective breeding of rohu for improving the growth rate, carried out at CIFA, Bhubaneswar, has given rise to a faster growing strain 'Jayanthi rohu' which is now distributed to farmers. The Mangalore Fisheries College has been carrying out selection experiments for *Labeo fimbriatus* and, under a NORAD assisted programme, CIFE has initiated selection experiments on *Penaeus monodon* and *Macrobrachium rosenbergii.*

e. Transgenic fish

Research on transgenic fish is being conducted at MKU, Madurai, in collaboration with CCMB, Hyderabad, and CIFA, Bhubaneswar. At MKU, transgenic zebra fish, rohu and *Heteropneustes fossilis* have been produced. For the zebra fish *Brachydanio rerio*, the gene constructs used were synthesised abroad from species such as the rainbow trout, while in rohu and *H. fossilis* the growth hormone genes of these species were identified, isolated, sequenced and incorporated into vectors prior to gene transfer. The potential hazards in consumption of transgenic fish — a genetically modified organism (GMO) — on human health need careful assessment, as in the case of GMO vegetables and fruits. The ecological impact of releasing transgenic fishes in open waters is not yet tested. Biological containment of transgenic fish by inducing sterility is a priority. The ethical and biosafety issues need to be addressed before introducing transgenic technology to aquaculture.

III. INBREEDING

Inbreeding leads to genetic homozygocity. This, in turn, leads to reduction in growth and food conversion efficiency, increased abnormalities in the progeny, and poor survival rates — in short, inbreeding depression. This has been happening in the carp hatcheries in West Bengal and elsewhere. The rate of inbreeding was estimated in south Indian carp hatcheries to vary between 2 and 17 per cent. Stunted growth and irregular body shape combined with skeletal deformities have been observed in hatchery-bred silver carp, mrigal and *Tor putitora.*

IV. CRYOPRESERVATION

Storage of fish milt, eggs and embryos without loss of viability is of considerable importance in aquaculture, as this would make available gametes throughout the year and superior germplasm easy to transport over long distances. It greatly benefits selection and hybridisation programmes. A very important function is that it helps in the development of a gene bank for conservation by cryopreservation of our natural fish genetic resources.

NBFGR has taken a lead in the cryopreservation of fish gametes and has developed cryopreservation protocol for 14 species of teleost, which include some endangered and highly endemic species such as *Tor khudree, Labeo dussumieri* and *Horabagrus brachysoma.* Ultra-structure studies have been conducted for refining cryopreservation protocol. Cryoprotectant and dilutant solutions for fish sperm have been developed. Attempts have been made to cryopreserve nauplii of *Penaeus monodon* and gametes of *P. semisulcatus* and *P. indicus* with limited success. With proper cryoprotectant, it has been possible to successfully cryopreserve the freshwater cladoceran *Moina* — so important as live feed for shrimp larvae in hatcheries.

V. GENETIC INTROGRESSION

Unintended intergeneric hybridisation and back crossing of F1 hybrids with their parents could result in genetic introgression among fishes, causing contamination of their gene pools. The rate of genetic introgression among Indian major carps produced during mixed spawning in Chinese model hatcheries has been recorded as 7.25-9.24%. Research has suggested modifying the hatcheries to have species-wise hatching pools to facilitate the breeding of the three Indian major carps separately, but within the same time span.

B. Marine Fisheries, Coastal Aquaculture and Mariculture

1. MARINE CAPTURE FISHERIES

In the early years, the major research input was towards faunal studies and fish biology such as studies on phyto- and zooplankton, fish eggs and larvae, age, growth and reproduction, food and feeding habits, and related subjects. So also, with the meagre seagoing facilities available, coastal oceanographic studies were conducted in a limited number of areas. Fish biology studies were mainly focussed on some of the major constituents of fisheries such as the oil sardine, other clupeids, mackerel, Bombay duck, the larger croakers, and some of the regionally dominant species like the silver bellies and carangids.

In the years following World War II, the expansion of fishing in the temperate waters and the extension of industrial fishing necessitated management interventions and this saw a surge of research activity in fish population dynamics and fish stock assessment. Most of the models and methods were developed in the context of temperate water systems, where fisheries are characterised by the single species and single gear system, supported by species that have long lifespans and clearly defined spawning periods and breeding grounds. This also facilitated the determination of age structure of the exploited stocks, which formed the basis for most of the fishery assesment models. The pre-1970 fisheries work in India was thus, by and large, based on the idea that the fishes, especially sardine, mackerel and even penaeid shrimp had longevity over several years as in temperate waters. Until the mid-1970s, the fish stock assessment in the marine fisheries was primarily based on the catch-effort relationship, and in some cases population parameters were based on age structure estimated from fish scales and otoliths (ear bones). However, such assessments carried out over different years yielded divergent and highly variable parametric values. The Maximum Sustainable Yields (MSYs) in most cases were grossly underestimated and estimates of age for the same species varied considerably. Such internal inconsistencies were never validated, and perhaps, could not be validated because of the methodological and data constraints. The futility of such exercises became increasingly evident in the early 1970s, especially the non-applicability of models and methods developed for temperate waters for the multi-species tropical fisheries. Most of the exploited stocks in Indian waters have short lifespans and protracted spawning seasons, which precludes objective determination of the age-structure of the exploited stocks. We now know that some enter the fishery even before or during their 1st year, and by the 2nd or 3rd year they are no longer there. So also, species of penaeid shrimp mature and spawn 6-8 months after hatching! The multi-species and multi-gear fishery system further compounded the problem. All these have led to alternative approaches for tropical fish stock assessment.

a. Population dynamics and stock assessment

The mid-1980s witnessed intense activity round the world in tropical fish stock assessment, culminating in the development of length-based stock assessment methods and models. The advent of packages such as LFSA, ELEFAN, and LFDA incorporating a suite of length-based stock assessment methods accelerated fish stock assessment and created greater awareness among research workers, fishery administrators and stakeholders on the need for fishery management. Thus fish stock assessment and fishery management continues to be based on the new techniques, with improvements as and when required. High speed personal computers and matching software have facilitated simulation modelling for depicting the complex dynamics of a fishery in a very user-friendly manner, enabling development of various management scenarios. This is a comprehensive tool where socio-economic, biological, ecological and environmental implications of various management options can be visualised.

More recently, multispecies stock assessment and an ecosystem approach to fishery management has been taken up, since a holistic approach, taking into consideration the trophic interactions, is so essential for understanding the dynamics of the exploited fish stocks. The 'Ecopath' model developed by Polovina in 1984 has been further expanded for application in complex fisheries issues. For the first time in India, a trophic model of the fisheries ecosystem of the southwest coast of India has been developed by CMFRI.

CMFRI has developed a Multistage Random Sampling Technique and refined it for estimating the exploited marine fishery resources of the country as well as for obtaining data for fish stock assessment. This has enabled the Institute to develop the National Marine Living Resources Data Centre, which is supportive of fisheries research and management.

Short-term forecasts based on satellite imagery help in minimising the search time for shoaling fishes which congregate along current boundaries, slicks, areas of upwelling, submerged sea mounts and thermal fronts. Chlorophyll-a distribution patterns could also indicate spectral bands in which concentrations of herbivores such as sardines occur. A series of joint exercises were conducted along the west coast of India, in which the CMFRI, SAC, FSI, and NARSA participated, and this cooperative effort culminated in a national symposium on the utilisation of remote sensing as a tool in marine fisheries.

b. Fishery biology, marine biology and oceanography

The scientists of CMFRI during the past 55 years have considerably contributed through their research, to our knowledge of the life history and biology of most of the commercially important groups or species of fishes, crustaceans (penaeid and non-penaeid shrimps, crabs and lobsters), and molluscs (bivalves, gastropods and cephalopods).

N.K. Panikkar, P.R.S. Tampi and R. Viswanathan were deeply involved in the study of fish physiology, especially the milkfish *Chanos chanos* and its adaptation to fresh and brackish waters. P.R.S. Tampi was also a pioneer in marine fish farming, as he experimented successfully with milkfish culture at Mandapam Camp, but could not follow up this line of research since marine fish farming was not in fashion then. R. Raghu Prasad's work on the swarming of *Noctiluca* in Palk Bay and its effects on the local sardine fisheries, and studies on the plankton of the Gulf of Mannar were important contributions. His research with P.V. Ramachandran Nair in 1960, on primary production and its relation to fisheries in the Gulf of Mannar added considerably to our knowledge and showed that tropical waters are not "barren deserts" as was then believed by many scientists in the west. During the 1950s, work on seaweeds gained much importance. Thivy developed a method for producing *Gracilaria edulis* agar in which freezing is not obligatory. The research of V.K. Pillai added considerably to our knowledge on the biochemical aspects of seaweeds. Jayaraman and his colleagues, in 1959, reported on the trawl fishery of the Bombay and Saurashtra waters.

Late Dr. S. Jones was an authority on fish eggs and larvae of both freshwater and marine fishes. He contributed a number of papers on the subject and some were published in this *Journal.* As Director of CMFRI, he steered the research programmes on tuna and tuna-like fishes in the Indian seas and made a comprehensive study of the tuna live bait fishes of the Lakshadweep Islands. His *magnum opus,* "The Fishes of the Laccadive Archipelago" published jointly with M. Kumaran, describing, with illustrations, over 600 species, is the most exhaustive work on the marine ichthyofauna of this region to come out in recent years. It has also added much to our knowledge of the species diversity of the coral reef ecosystem of the Lakshadweep.

His founding of the Marine Biological Association of India in 1958 was a significant event, as the Association has a history of fostering marine biological, oceanographic and fishery research through its journal and special publications, as well as the national and international symposia on various aspects of marine resources, their utilisation, conservation and management that it has held from time to time. In 1961, the first International Symposium was held on Scombroid Fishes, followed later by Symposia on Crustacean Fisheries; Molluscan Fisheries; Coral Reefs; Endangered Marine Animals and Marine Parks; Indian Ocean, its Origin, History and Resources; Coastal Aquaculture; and so on, and the proceedings of all the symposia were published.

Dr. S.Z. Qasim, who succeeded Dr. Jones as Director of CMFRI, brought a lot of dynamism to marine fisheries research and the mariculture programmes. It was during his tenure that cultured pearls from the pearl oyster *Pinctada fucata* were produced. The protocol for cultured pearls using indigenous technology was standardised.

In the 1960s, the study of demersal fishery resources of the northwest coast based on catch and effort over a period of time, gave us for the first time, a detailed textual and illustrative account of the resources. For the first time, fishery oceanographic studies were conducted along the west coast of India on board the *R.V. Varuna* of the erstwhile Indo-Norwegian Project, Cochin. Deep-water surveys beyond the continental shelf along the upper continental slope enabled the discovery of many new resources and resource complexes such as the deep-sea lobster and shrimp resources, deepwater fin-fishes, sharks and crabs. Acoustic surveys were also conducted for the first time to locate "Kalava grounds". Silas reported on the Deep Scattering Layer (DSL) and its constituents in the Lakshadweep Sea. Scientists were able to find a correlation between humidity, barometric pressure and mackerel fishery. So also, it was found that there was a pivotal surface temperature at which mackerel spawn. It was also shown that upwelling along the shelf waters of the west coast commenced as early as February and was not monsoon induced. The decade of the 1960s showed the need for having an integrated approach while studying marine fishery resources, as fishery-independent physico-chemical parameters play an important role. The investigations conducted during the exploratory fishery surveys of the northwest coast and continental shelf waters by the Polish research vessel *Maurena* pointed to the limitations in demersal fishing ground resources, while finding untapped pelagic resources such as horse mackerel in sizeable population.

A tagging programme of pelagic fishes (mackerel and sardine) and shrimps (*Penaeus indicus*) gave valuable information on their growth and migratory behaviour from tag recoveries. Very significant was the recovery of *P. indicus* tagged off Cochin and recovered after 66 days from the Gulf of Mannar, off Manapad, about 400 km away.

The euphoria over the assumedly limitless capture fishery resources started crumbling with the collapse of the Peruvian anchovy fishery due to the *El Nino* phenomenon and of the North Sea mackerel and herring fisheries due to overfishing. These and many other instances brought about the need for alternate strategies to augment fish production through discovering new fishing grounds and resources, and utilising the normally discarded as well as underutilised and non-conventional resources. Besides this, the strategy was to also develop coastal aquaculture and mariculture.

c. Coastal aquaculture and mariculture

In the early 1970s, a major research effort was made to develop coastal aquaculture (in estuarine, coastal brackishwater lagoons and wetlands) and mariculture (sea farming), though there was considerable scepticism as to whether the programmes would succeed and be viable in the absence of any expertise. The assumption was that it would be too expensive, considering situations such as that which the Coca Cola got into after investing several million dollars in shrimp farming, or the long duration of the culture of 'Kurma' shrimp (*Penaeus japonicus*) in Japan (nearly 14-18 months), and the lack of information about captive hatchery breeding.

In view of the dwindling resources in capture fisheries and the great demand in the export trade for shrimp, culturing shrimp was given high priority. Within a year after the programme was taken up, it was possible to mature and breed, at the Narakkal (Cochin) farm of CMFRI, all the important penaeid species occurring along the southwest coast, namely *Penaeus monodon*, *P. indicus* and *Metapenaeus dobsoni*, and in Chennai, namely *P. semisulcatus* and *P. japonicus*. Procedures were standardised and after stocking in the ponds, it was possible to harvest the shrimp in 3-4 months.

The situation was in no way different for other marine organisms. For instance, in the case of edible oyster *Saccostrea madrasensis*, after the mature oysters were induced to spawn and after successful spat settlement and transfer of the spat to submerged racks, harvesting was done in 10 months. In the pearl oyster *Pinctada fucata*, after implantation of nucleus, good lustrous pearls could be obtained in 6-8 months depending on the size of the nucleus. Likewise in the case of mussels, *Perna virdis* and *P. indica*, in open sea culture on ropes suspended from floating rafts, the harvest was done in 4 months by which time 3-4 kg of seed implanted on a 7-metre long rope could yield 80 to 100 kg shell mussel; a single raft of 6 m x 10 m could take 12 or more ropes. In the case of the spiny lobster *P. homarus*, through eye ablation technique and feed, it was possible to obtain from juveniles of 30 to 40 g, a marketable size of 100 g in 10 months, and in *P. ornatus*, from 200 g, 1.2 kg could be obtained in the same period. Fast growth was the case with all the fin fishes bred in the hatcheries and cultured in the farm, such as grouper *Epinephelus tauvina*, sea bass *Lates calcarifer*, mullets (*Mugil* spp.), pearl spot *Etroplus suratensis*, tilapia and other species. The eel *Anguilla bengalensis* took about a year from elver to marketable size with partial success of inducing maturation in the male. A good facility for grouper culture has been developed at Mandapam Camp. It is today possible to culture the sea cucumbers *Holothuria scabra* and breed them.

A special mention is needed about the ongoing mariculture and research facilities at the Central Agricultural Research Institute at Port Blair, Andamans. Blessed with good quality sea water, active work on the breeding of ornamental and other fishes, crustaceans and pearl oysters including the black lip pearl oyster *Pinctada margratifera* is going on.

In the culture of agar producing seaweed, *Gracilaria edulis*, excellent results have been obtained in floating coir network in which vegetative parts are implanted.

d. Centre of Advance Studies in Mariculture

The newly started mariculture research programmes of CMFRI in the 1970s was to some extent hampered by a lag in research, teaching and trained manpower. The techno-economic feasibility of the projects taken up as well as the transfer of technology and manning of hatchery and farm operations, to the existing staff needed considerable reorientation and at the same time nurturing a new generation of scientists. In 1979, a Centre of Advanced Studies in Mariculture was established at CMFRI, Cochin. It facilitated dozens of scientists from the Institute to go abroad for training in specialised subject areas such as fish and shrimp nutrition, reproductive physiology, fish genetics, endocrinology, fish and shellfish pathology, live feed cultures, hatchery technology, etc.

RESEARCH ON BRACKISHWATER AQUACULTURE

The recent research advances at CIBA are in the maturation, breeding and hatchery development of penaeid shrimp. Specially formulated economical feeds with good conversion efficiency have been developed for shrimp. Captive brood stock development of fin fishes such as *Etroplus suratensis*, *Lates calcarifer* and *Mugil cephalus* has been streamlined for technology transfer to fish farmers.

RESEARCH ON SHRIMP, FISH AND SHELLFISH PATHOLOGY AND DISEASE MANAGEMENT

Diseases were a bane of shrimp aquaculture in the 1990s and still continue to plague the industry. At least four diseases with proven viral etiology have been reported from India, namely, the White Spot Syndrome Virus (WSSV), Monodon Baculovirus (MBV), Hepatopancreatic Parvo Virus (HPV) and Infectious Hepatopancreatic and Lymphoid Organ Necrosis (IHLN). Due to WSSV, there has been an annual fall of 10,000 to 15,000 t of shrimp valued at Rs. 300 to Rs. 500 crore, or a cumulative loss of over Rs. 2,000 crore during the last 6-7 years. This has also affected the livelihood of a number of shrimp farmers and has been a setback to the industry. This explains the reason for the number of national organisations and universities involved in the study of shrimp and fish pathology during the last ten years.

Research on Fish Diseases

During the 1980s and 1990s, fish culture in most parts of India and natural fish populations in rivers and lakes were seriously afflicted by Epizootic Ulcerative Syndrome (EUS), where the fish developed lesions on the body. CIFA, Bhubaneswar developed a medicine "Cifax®" to control the disease. The Institute was also able to suggest water quality standards to prevent the spread of the disease that badly affects carps, catfishes, murrel and other fish. Vaccines are being developed using RFLP (Restriction Fragment Length Polymorphism) and PCR techniques. Research on immune response of Indian major carps to *Aphanomyces invadens*, the fungal pathogen of EUS is ongoing.

Disease Management

A multi-pronged approach is being adopted to handle disease prevention and control involving Chemoprophylaxis and Chemotherapy, vaccines, immunostimulants, probiotics, specific pathogen-free (SPF) shrimp, specific pathogen resistant (SPR) shrimp, high health shrimp, and development of genetically resistant stock. With new rapid diagnostic techniques, it is possible to screen brood shrimp and shrimp seed before stocking them in ponds and to monitor the grow-out phase for viral and bacterial pathogens. A new concept, involving stimulation of the shrimps' immunity termed 'immunostimulation' has come up, as an alternative to vaccines against bacterial and viral diseases; the technology is being developed and transferred to the industry by the Microbiology Department, College of Fisheries, Mangalore. They also have a promising research programme on microorganisms antagonistic to pathogens or with anti-vibrio activity (*Pseudomonas* strains). Besides this, some groups of biological and synthetic compounds such as glucans are used to enhance the non-specific defence mechanisms in shrimp. To mitigate the disease problem and to enhance pond ecosystem, research on crop rotation as a health management tool is underway. A new research approach at the College of Fisheries, Mangalore has been the promotion of microbial film in ponds to enhance the quality of fish production.

A considerable amount of research for developing management strategies has been done and is ongoing at the Department of Microbiology, the UNESCO Centre for Marine Biotechnology, the Centre of Bioinformatics, and the Department of Aquaculture at this College, and at the Genetics and Biotechnology Division of CIBA.

Fish and Shellfish Toxicity

Marine toxins and harmful algal blooms seriously affect public health and fish and fishery products. There is a world watch on the occurrence of such harmful algal blooms that lead to shellfish toxicity and fatalities. For the first time in India, Paralytic Shellfish Poisoning (PSP) was reported from the west coast. The first record of diarrhetic shellfish-toxin producing dinoflagellates was made from India and the PSP toxins were analysed. The toxic alga (*Gymnodinium nagasakiensis*)-caused red tide and fish kills were reported from Someswar on the west coast of India.

A more recent outbreak of PSP has been recorded from Vizhinjam, south Kerala, where over 500 people were hospitalised and seven died. The Marine Science Department of the Cochin University of Science and Technology (CUSAT) was designated as the nodal centre for India in the global network of the "Mussel Watch" Programme. A PCR-based detection method for toxic dinoflagellates has been developed. In this background, a major national research programme on Toxic Algal Blooms in the Indian Exclusive Economic Zone (EEZ), under the auspices of the Department of Ocean Development, Government of India, is underway at CUSAT, Cochin.

RESEARCH ON HARVEST AND POST-HARVEST TECHNOLOGIES

I. FISHING TECHNOLOGY

Research on appropriate design of fishing crafts and gear was initiated from the very inception of the CIFT and today 90% of the mechanised fishing vessels in the length range 7.6 to 15.2 m are built on one of the 12 designs developed by the Institute. A steel fishing trawler (15.5 m) has also been designed and is in commercial operation today. A fuel efficient nozzle propeller that reduces fuel consumption was also designed by the Institute. Various cost effective protective measures against biodeterioration of wooden fishing vessels have been developed and are in use. A number of non-timber building materials such as ferro-cement, fibreglass reinforced plastic (FRP) and toxic non-plastic composites have been tested as alternative boat building materials. Cathodic protection of fishing boats and metallic marine structures with a galvanic ternary aluminium, free from mercury, has been developed, and is eco-friendly, non-polluting, cost effective and durable.

II. FISHING GEAR

The development of combination wire rope as an import substitute for deep-sea fishing is a recent innovation which has now been commercialised. CIFT has standardised specifications for the use of polypropylene multifilament netting yarn with lower specific gravity and better tenacity than nylon. Research on fishing gear has led to innovative concepts and designs for multipurpose gear such as the high opening trawl, high-speed demersal trawl, hybrid trawl, bobbin trawl, large mesh trawl, rope trawl, semi-pelagic trawl with flexible headline and lifting devices, and mini-purse seine.

More research has gone into the development of by-catch reduction devices such as the radial escape device that facilitates escape of young and juvenile fish and by-catch from the trawl. The Turtle Excluder Device (TED) has also been successfully field tested and incorporated in the trawl nets. The device permits cent per cent escape of turtles (*Lepidochelys olivacea*), and escape of fish and shrimp in the catch is as low as 1.2% and 0.62% respectively. CIFT has also developed a new durable lobster trap which is widely used. Research on the right type of packaging for fish products has led to considerable improvements in the quality of the products. An emerging new area is the live transport of fish and crustaceans.

III. FISH PROCESSING TECHNOLOGY AND PRODUCT DEVELOPMENT

A wide variety of value added individually quick frozen (IQF) products and specialised products such as dehydrated jellyfish, *bêche-de-mer*, high quality "maasmin" from tuna, fish wafers, soup powders, battered and breaded products have been developed and commercialised.

Research on utilisation of fish products has been high on the agenda as fishery by-products find application in several fields. A major thrust in this area was the development of many innovative programmes which furthered international contacts of the Institute in the area of product development and value addition. Chitin and chitosan from prawn shell waste are two such products that have a wide spectrum of uses. The uses of chitin in broiler chick feed for weight gain, and for production of glucosamine hydrochloride that has application in antibiotics and baby food formulations, are well known. Chitosan has innumerable uses. Research on fish collagen, prepared from fish air-bladders, has led to a wide variety of uses. A new application has been the preparation of collagen-chitosan film which can be used as artificial skin for treatment of burns and also as a barrier device in dental surgery for Guided Tissue Regeneration (GTR) in cases of furcated gums. It is much superior to the presently used teflon which needs surgery for removal after tissue regeneration. Absorbable surgical suture, a bio-product, so important for healing of wounds after surgery has been developed from fish guts. The absorbable extra-fine sutures which are prepared from fish gut collagen by cross linking and polymer coating, have been found suitable even for eye and other microsurgery.

CIFT has also developed a procedure for processing shark cartilage rich in chondriotin sulphate into a clean, dry and attractive material that has application in medicine for treatment of arteriosclerosis, blood vessel thrombosis and prevention of infection.

The Institute has developed software for Hazard Analysis Critical Control Point (HACCP), a modern tool for implementation of quality assurance and safety in the seafood processing industry.

ROLE OF THE DEPARTMENT OF OCEAN DEVELOPMENT IN FISHERIES RESEARCH AND THE ANTARCTIC PROGRAMME

The Department of Ocean Development (DOD), Government of India from its inception in the early 1980s has played a major role in facilitating fisheries and oceanographic research in the Indian EEZ as well as the contiguous high seas. It acquired a new *Fishery Oceanographic Research Vessel* (*F.O.R.V.*) *Sagar Sampada*, built in Denmark with all-weather ocean-going capabilities and equipped with the most sophisticated acoustic, oceanographic and meteorological equipments. Besides, it has the capability of operating fishing trawls at depths up to 1,000 m. CMFRI was given the responsibility of running the research programmes of this vessel.

The DOD has also established a new Institute, the National Institute of Ocean Technology (NIOT) to address specialised ocean technology problems. Its facilities are also available for the marine fisheries research programmes.

Ever since 'Operation Gangotri,' the First Indian Expedition to Antarctica was undertaken in December, 1981 under the leadership of S.Z. Qasim, and its first research station 'Dakshin Gangotri' established, India has been sending an expedition consisting of multidisciplinary teams to Antarctica every year. The Commission for Conservation of Antarctic Marine Living Resources (CCAMLR) manages the fishery and conservation of the Antarctic marine ecosystem and krill. India is one of the 23 Member Countries of the Commission.

The Antarctic Ocean supports biological communities of a few species with large populations, the most important of which, the shrimp-like krill, regulates the food chain. The Indian effort in studying the fishery resources of the region was the First Indian Antarctic Krill Expedition conducted by DOD in the area 58° 56' - 61° 17' S and 30° - 40° E.

DISSEMINATION OF RESEARCH RESULTS

The research results are published both in Indian and foreign scientific journals. The ICAR-controlled fisheries research institutes have also a nodal journal, *The Indian Journal of Fisheries* published from CMFRI. Each institute has its own scientific association which also runs its own scientific journal. Some of the Associations are very active and organise national and international scientific meetings, symposia, seminars and workshops and publish proceedings of these. The Institutes bring out a lot of extension literature, especially for transfer of proven technologies.

CONSERVATION OF MARINE LIVING RESOURCES AND MARINE HABITATS

The international conferences and conventions held in various parts of the world during the last few years have drawn attention to the need for maintaining the marine biodiversity and protection of marine habitats and endangered species. A marine habitat such as the mangrove ecosystem is also a grow-out system for many species of marine fishes and crustaceans, and for some species, a spawning area as well. If these habitats are left unprotected, with human depredation, recruitment to the fisheries gets adversely affected.

A recent happening forcefully draws attention to the need for sound research data in order to provide scientific advice for making management decisions that will also stand the test of jurisprudence. The case in question is the ban imposed on fishing of elasmobranch fishes (sharks, skates and rays) which, for reasons unknown, were placed under Schedule I under the Indian Wildlife (Protection) Act by the Ministry of Environment and Forests, Government of India. The ensuing dialogues and debates resulted in back pedalling and short-listing the number of species to nine, though there is no justification for a ban on others on the list. A silver lining, though, is the major funding from the Ministry of Environment and Forests for research on elasmobranch fisheries, status of species and management issues, which is in the pipeline.

Fisheries research must help to tackle the conflicts that we see today in marine capture fisheries and the maladies in coastal aquaculture. Sharing common resources even within the territorial waters, the question of straddling stocks and highly migratory pelagic fishes, restoring habitats and fish stocks to original sustainable levels through sound management strategies involving a participatory approach of the stakeholders, and many other problems need to be addressed. A large infrastructure for fisheries research and trained manpower has been built up during the past three decades, and this has to be put to the best use in public interest. The focus, as mentioned by Anne Platt McGinn (quoted at the beginning of this chapter), should be shifted from what is done to the fish to what can be done for the fish.

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HISTORY OF MARINE SCIENCES (EXCEPT ICHTHYOLOGY) IN INDIA

B.F. CHHAPGAR[1]

Key words: Indian marine science organisations, early marine biologists, history

The history of marine science is, in fact the history and achievements of several institutions and organisations, mainly governmental but also a few learned societies and many individual scientists' contributions. As Calcutta was the earlier capital of British India, pioneering studies naturally started there and flourished. Parallel to the natural history studies and animal and plant collections of the Bombay Natural History Society, leading to the establishment of the Prince of Wales Museum in Bombay, the Indian Museum — itself the offspring of the Royal Asiatic Society of Bengal — was the progenitor of the Zoological Society of India. Its sister institution, near Calcutta, is the Botanical Survey of India. The Marine Survey of India, most well known for the deep-sea investigations by *R.I.M.S.S. Investigator*, was one of the first to pursue marine sciences, and can be considered the "Father" of the National Institute of Oceanography and the Department of Ocean Development which had its own ship *O.R.V. Sagar Kanya* and had annual forays to Antarctica.

Other British Indian territories in peninsular India were the Madras Presidency which extended to Malabar and South Kanara on the west coast of India and Bombay Presidency which even included Sind (now in Pakistan). Pioneering marine biological studies were carried out here. Bombay has the popular Taraporevala Aquarium with its connected Taraporevala Marine Biological Station. It is also the Headquarters of the Fishery Survey of India and the Central Institute of Fisheries Education, a Deemed University. The erstwhile Madras Presidency was fortunate in having some of the richest coral reefs in the Gulf of Mannar, and the Bulletins of the Madras Government Museum, especially the series covering Krusadai Island, are the predecessors of the present day *Bulletins of the Marine Biological Association of India.*

Among the princely states, Travancore, Cochin and Baroda had enlightened maharajas who sponsored and encouraged prime studies in marine biology. The former two, now part of Kerala, house the head offices of the Central Marine Fisheries Institute and the Central Institute of Fisheries Technology at Ernakulam, and their universities have been consistently doing yeoman research in marine biology and oceanography. Although Baroda State was landlocked, its territories included Okha and Kodinar. The farsighted Gaekwads (rulers) of Baroda State utilised the services of English marine biologists to carry out extensive surveys of Okhamandal, as it was then known, the richest coral reef area on the mainland's west coast.

INTRODUCTION

India has stood out for nearly two thousand years as a maritime subcontinent, with sea trade connections from Africa, Madagascar and Arabia in the west to Indonesia, Cambodia and China in the east. This necessitates a grasp of navigation, monsoon winds, currents and tides. From this, one would believe that our coastal people would also have acquired knowledge of the organisms dwelling in the sea, but such knowledge was confined to large ones like whales and sharks, from their carcasses sometimes washed ashore. There are ample references to animals in Indian mythology, legends and folklore, but, with a few exceptions, these pertain to mammals, birds and reptiles. Vedic texts mention only a few marine animals such as the chank (*sankha*) and pearl-shells; one can only conclude that Vedic civilisation came into very little contact with maritime states and civilisations (Rao 1957). It was left to European naturalists who ventured to our country, for trade and subsequent colonisation, to lay the foundations for marine biology.

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One of the earliest descriptions of an Indian marine animal dates back to 'Observations made on a tour made from Bengal to Persia in the years 1786-87' [p. 236 in PINKERTON'S VOYAGES AND TRAVELS (1811)], wherein Ensign W. Francklin states that "the most remarkable animal curiosity the island" — he refers to Bombay (=Mumbai) — "produces is a small fish... about four inches long, (having) upon the top of its back and near the head, a small valve on the opening of which you discover a liquor of a strong purple colour which when dipped on a cloth, retains the hue. It is found chiefly in the months of September and October. (This obviously refers to the sea-hare *Aplysia.*)

The first record of seaweeds is based on Wallich's marine algae preserved on herbarium sheets in 1822. This predates Wight's collection in 1826 from the coast of 'Hindustan' and Madras (published in PRODROMUS FLORAE PENINSULAE INDIAE ORIENTALIS) in 1834.

Among the several scientific organisations in India, only a few deal exclusively with marine sciences. Thus, many universities and even some governmental institutions, which have various pure and applied sciences as their main objectives, also include marine biology. Over the years, the impact of physics, chemistry, geology and meteorology have merged to make marine sciences a multi-disciplinary subject. For the sake of convenience, the marine sciences are dealt with state-wise.

WEST BENGAL

Any reference to the history of marine science would be incomplete without the inclusion of five organisations, none of which deals exclusively with marine sciences, but all five of which are interlinked. These are: the Asiatic Society of Bengal, the Marine Survey of India, the Indian Museum, the Zoological Survey of India, and the Botanical Survey of India.

The Asiatic Society of Bengal

The Asiatic Society of Bengal was founded in 1784 by Sir William Jones to "elucidate the peculiarities of Art and Nature in the East"; at that time it was known simply as the Asiatic Society. The Society's Journals and Proceedings were popular receptacles for erudite scientific papers, and naturalists sent zoological specimens to the Society for examination and retention. Sir William Jones was opposed to the idea of collecting zoological objects, as he felt that this entailed the destruction of wildlife. Nevertheless, the number of specimens built up to such an extent that in 1796, it was thought fit to have a suitable building to house the Society. In 1808, the Society finally came to have its own building, and its museum, popularly known as *Jadu Ghar* (house of mysteries) was established in 1814.

Dr. Nathaniel Wallich combined his duties as Superintendent of the East India Company's Botanic Garden with the superintendentship of the Asiatic Society's museum. In 1836, there was a scam in the Society's bankers, Palmer & Co., and appeals to the government for financial support were finally heeded in 1839. On Wallich's retirement, the new Curator was John McClelland, a distinguished naturalist, followed in 1841 by Edward Blythe.

In 1936, the King of England was pleased to permit the Society to use the prefix "Royal"; thus it became the Royal Asiatic Society of Bengal.

The Marine Survey of India

This was established in 1874 by the Government of India, at the request, in 1871, of the Council of the Asiatic Society of Bengal, which recommended the undertaking of deep-sea dredging in Indian waters.

The primary aim of marine survey is the safeguarding of navigation along the local lines of commerce by making charts and sailing directions for mariners, local peculiarities of currents and tides so as to make a safe approach to land, and conditions of ports and harbours for shelter and supplies. Added to this was a secondary purpose — that of obtaining knowledge of the hydrography of local sea-basins, their depth and temperature, deposits forming in their abysses and the life that inhabits them. For the latter purpose, officers called Surgeon-Naturalist formed a complement of the ship; they were medical personnel looking after the health of the crew, but were also interested in biology and involved themselves in scientific studies.

The surveying of Indian waters is an old undertaking. Prior to the Marine Survey of India, marine surveys were conducted by the Indian Navy from 1832, to 1862 when this service was abolished. These operations covered an extensive area from Iraq to Seychelles, and involved the upper reaches of the Rivers Euphrates and Tigris, the ruins of Nineveh and Babylon, and the discovery of the source of the River Oxus. Dr. H.J. Carter, F.R.S., a medical officer in the Indian Navy, became a leading authority on the lower invertebrates, especially sponges, while Dr. Theodore Cantor specialised in the fishes of Malaysia.

Even before the advent of the Indian Navy, marine surveys were carried out, from the Red Sea to China, by the Bombay Marine.

From 1874 to 1881, the Marine Survey had no ship capable of deep-sea research, so that the first Surgeon-Naturalist, J. Armstrong of the Indian Medical Service, had to confine himself to the zoology of the shallow-water and littoral region, though he did occasionally manage to dredge down to 150 m.

In 1876, it was decided to construct a ship suitable for deep-sea dredging. This was built at Bombay, which was then renowned for the quality of its boats and carpentry skills of the Parsee master-craftsmen. While English ships made of oak wood hardly lasted twenty years, those made of teak by Bombay's Parsee boat builders, brought from Surat by the English, have survived for seventy, eighty and even a hundred years. The ship, named the *R.I.M.S.S.* (*Royal Indian Marine Survey Ship*) *Investigator*, was a paddle-steamer of 580 tons displacement with two funnels, and was launched in 1881. (An account of its history and equipment may be seen in the *Scientific Memoirs of the Medical Officers of the Army of India* for 1898.)

The *R.I.M.S.S. Investigator* was not the first ship of its name; it had illustrious predecessors. In 1850, a ship of this name set out to discover the fate of Sir John Franklin and his ship, which had left England in 1846 in search of a northwest passage from the Atlantic to the Pacific Ocean. Some channels in the Mergui Archipelago have been named after another ship, *Investigator*, of the Bombay Marine.

While the *R.I.M.S.S. Investigator* was being built, the mother of all oceanographic expeditions — *H.M.S. Challenger* — was just over. The excitement caused by the sensational discoveries of deep-sea life led the Asiatic Society of Bengal to ask the government to equip the new vessel for deep-sea dredging. The outcome was that a substantial portion of the oceanographic equipment used on *H.M.S. Challenger* was transferred to *R.I.M.S.S. Investigator*.

After Armstrong relinquished his post in 1879, the post of Surgeon-Naturalist remained vacant until 1894, when Surgeon G.M.J. Giles took over. In the meantime, the Trustees of the Indian Museum sent Dr. J. Wood-Mason to the Andaman Islands to investigate the fauna, and he managed to carry out trawling at depths of 180 to 540 m on board the Guard-ship, *S.S. Undaunted*. From then on till 1904, was the heyday of deep-sea dredging and trawling by *Investigator* in depths as great as 3,650 m. More than 70% of the species of deep-sea animals brought up by the *Investigator* turned out to be new to science.

Lt. Col. A.W. Alcock, who joined as Surgeon-Naturalist in 1888, until 1892, was one of the most notable scientists connected with the *Investigator*. With a chequered career varying from a teacher of Classics in Darjeeling and an assistant on one of the plantations in Bihar, to Medical Officer with the Punjab Frontier Force and Deputy Sanitary Commissioner, Bengal, he was to carcinology what Sir Francis Day was to ichthyology in India, his *magnum opus* being the series of papers from 1895 to 1900 titled "Materials for a Carcinological Fauna of India."

By the beginning of the 20th century, the work of the Marine Survey of India had attracted so much attention that, when H.R.H. Prince Albert I of Monaco erected the now world-renowned Institute of Oceanography, the name of *Investigator* was carved on its facade, along with other equally famous oceanographic ships such as *Challenger*, *Travailleur*, *Talisman*, *Gazelle*, *Novara* and others.

In 1908, *R.I.M.S.S. Investigator* was scrapped and was replaced by *Investigator II*; this was a steel ship of 1,018 gross tons built by Vickers Maxim & Co. in the U.K. Lt. Col. R.B. Seymour Sewell joined as Surgeon-Naturalist in 1910. By then more emphasis was placed on investigations of the seas.

With the outbreak of the First World War in 1914, survey was suspended, and resumed only in 1921. Thereafter, survey of the Maldive Archipelago and Nicobar Islands was begun, so Sewell studied the corals in the region. In 1925, Sewell left the Marine Survey to take up the post of Director, Zoological Survey of India, and Major R.W.G. Hingston replaced him as Surgeon-Naturalist, but only for a year. The post of Surgeon-Naturalist was converted to Naturalist to the Marine Survey, attached to the Zoological Survey of India. However, the post was not filled up, so the work of Surgeon-Naturalist came to an end in 1926. After that, no Marine Survey organisation existed, so that work on marine fauna was restricted to shore collections. Then in 1959, the Zoological Survey of India started a small Marine Survey Unit (subsequently enlarged to a Marine Survey Division in 1964) based at Calcutta (=Kolkata). It acquired a research boat, named *Chhota Investigator* in 1975, fitted with hydrographical and survey equipment.

Consequent to the vast oceanographic and faunal studies carried out by the *Investigator*, numerous invaluable scientific papers have been published.

The Memoirs drawn up by the Council of the Asiatic Society of Bengal for proposals to the Government of India to undertake deep-sea dredging, and the letter forwarding the same, have been published in the *Proceedings of the Asiatic Society of Bengal*, 1871. Details of *R.I.M.S.S. Investigator*, its history and the equipment thereon are given in a paper titled "A summary of the deep-sea work of the Royal Indian Marine Survey Ship 'Investigator' from 1884 to 1897," published in the *Scientific Memoirs of the Medical Officers of the Army of India*, 1898.

The work done on the ship was published in several parts as "Natural history noted from Royal Indian Marine Survey Ship 'Investigator' " from 1885 in the *Journal of the Asiatic Society of Bengal.*

Zoological Survey of India

This organisation is covered in a separate chapter in this Centenary Volume. However, the author, Dr. J.R.B. Alfred's coverage of the pre-1947 history of the organisation is limited to field studies. Hence, it would not be amiss to include other historical background of the organisation's beginnings here.

The Zoological Survey of India (ZSI) owes its birth to a proposal presented to the Government of India by the Trustees of the Indian Museum which reads as follows: "If zoology is to play the role the age calls for, it must be freed from the constricting tradition of classification, literature and the arts." The Government of India agreed with the Trustees' views, with the result that the Zoological and Anthropological Sections of the Indian Museum were detached therefrom, and formed the Zoological Survey of India. (The Anthropological Section formed part of the ZSI until November 31, 1945.)

The ZSI's first Director was Dr. Thomas Nelson Annandale. With his appointment, taxonomic work was initiated on Decapod Crustacea, sponges and fishes. However, his major contribution has been the starting of the *Records of the Indian Museum* and the *Memoirs of the Indian Museum* in 1907.

When Dr. Annandale died in 1924, Dr. Stanley Wellis Kemp officiated as Director of ZSI. Earlier, in 1920-21, when Dr. Annandale had gone on leave to England, Kemp had acted as Director, and he proposed the establishment of a Marine Biological Station at Port Blair in the Andaman Islands, but nothing came out of the proposal. He had hardly been Director at ZSI for six weeks, when he left to become the first Director of Research of the *Discovery* Investigations. On Dr. Kemp's leaving ZSI, Dr. Baini Prashad officiated as Director until 1925, when Major Sewell took over again as Director, and remained so till his retirement in April 1933. The original post of Director was then abolished and instead, the designation of the Superintendent was changed to Director (but on the Superintendent's pay).

During the Second World War, enemy troops had advanced to Burma and Kohima in Nagaland, and there was fear about the safety of the collections of ZSI, which were housed in the Indian Museum, Calcutta. All type-specimens and Class I exhibits were therefore shifted to the Forest Research Institute, Dehra Dun, while the library, other collections and the staff were sent to Benares at Kaiser Castle, a number of semi-detached buildings on the River Varuna.

In September 1943, this river was in spate due to floods and its waters entered the underground cellars, remaining at ceiling height for two days and ruining the collections, library books and accession registers. In the resulting confusion, publication of the Records and Memoirs of the Indian Museum were suspended.

The ZSI was shifted back to Calcutta in 1948-49, to be housed at Jabakusum House on Chittaranjan Avenue. The library and Taxidermy Section went back to the Indian Museum premises. The Director's post was vacant from October 1973 to May 1977.

The *Records of the Indian Museum* and *Memoirs of the Indian Museum*, which had been suspended, recommenced in 1962, under the new names — *Records of the Zoological Survey of India* and *Memoirs of the Zoological Survey of India.* In 1976-77, a new series, *Occasional Papers of the Zoological Survey of India* was started, to be followed soon after by three new journals, namely, *Technical Monographs*, *Bulletins of the Zoological Survey of India* and *Handbooks of the Zoological Survey of India.* The monumental series *Fauna of British India*, started by the British in 1888, was renovated in 1975 under a new name — *Fauna of India.*

The foundation stone of the new Headquarters building was laid on November 18, 1976 at New Alipore, and ZSI finally shifted to this ten storey building, named Prani Vigyan Bhavan in 1987. With the establishment of the Department of Environment by the Government of India in November 1980, the ZSI came under its administrative jurisdiction. Eight acres of land were set aside at Digha (on the West Bengal coast) for setting up an aquarium-cum-research centre.

Botanical Survey of India

Towards the middle of the 19th century, the excellent work done at the Royal Botanic Gardens at Kew (in U.K., the Mecca of all botanists) began to guide the direction of botany in India. Advances in botanical studies, particularly plant collecting, in the 1830s and '40s led to the undertaking of two great enterprises, namely, the Flora of the higher plants, and the Indian Forest Service, resulting, ultimately, in Hooker's FLORA OF BRITISH INDIA.

The Botanical Survey of India was established much earlier than its sister organisation, the Zoological Survey of India, i.e. in 1890, with Sir George King as its first Director. However, it had a chequered history; after functioning actively for about a decade, it worked fitfully for three decades and lapsed into dormancy after the retirement of its last British Director, Dr. C.C. Calder in 1939.

It was long after India's independence from colonial rule, in 1955, that the Botanical Survey of India was revived, with the appointment of Fr. H. Santapau, S.J. as ad-hoc Director. He was followed by Dr. J.C. Sen Gupta as Chief Botanist.

The *Bulletin of the Botanical Survey of India* started in 1959, and a new Flora of India series was started, with its Fascicle coming out in 1978.

Coming back to the work done in West Bengal, mention must be made of the shallow water fauna trawled by the Bengal Fisheries Steamer *Golden Crown* in 1908-11, and those collected at the mouth of River Hooghly by the Bengal Pilot Service in the 1930s.

ORISSA

The most prominent faunistic work done in this State was on Chilka Lake; publications on these studies commenced in 1916, in the form of a Memoir (Vol. 5, Nos. 1-13) of the Indian Museum.

ANDHRA PRADESH

Probably all the marine biological work done in this State owes its excellence to the studies undertaken at the Department of Marine Sciences of the Andhra University at Waltair (Visakhapatnam). Established in 1926, the Department's studies veered towards oceanography in 1952 under the able guidance of Professors E.C. LaFond and P.N. Ganapati. Now there is also a Centre of Assistance in Marine Geology, Zoology, Geophysics, Meteorology and Oceanography.

TAMIL NADU

The erstwhile Madras Presidency was the earliest and foremost organisation to produce quality work in marine biology. This is borne out by the series of excellent Catalogues and Bulletins brought out by the Madras Government Museum, which are a tribute to the marine biologists of those days. The first *Catalogue of the Madras Government Museum* appeared in 1874, but dealt with ancient coins. The first Catalogue dealing with marine life appeared in 1887, and was written by E. Thurston under the title "Preliminary Report on the Marine Fauna of Rameswaram, and the neighbouring Islands." In 1890, the same author brought out a Catalogue titled, "Pearl and chank fisheries and marine fauna of the Gulf of Manaar."

The *Bulletin of the Madras Government Museum* started in 1894. The four parts of Vol. I are all written by E. Thurston and are titled: No. 1 - Pearl and chank fisheries of the Gulf of Manaar; No. 2 - Notes on Tours along the Malabar coast; and No. 3 - Rameswaram Island and fauna of the Gulf of Manaar (1895). (No. 4 is on anthropology.) It may be noted that the Madras Presidency then extended even to the Malabar (now in Kerala) and South Kanara (now in Karnataka) coasts of western India.

These Bulletins continued until 1907, but, except for Vol. III, No. 2, titled "Sea fisheries of Malabar and South Kanara" by Thurston, all the others deal with anthropology. After a lapse of several years, the Bulletins recommenced as a new series from 1927. Vol. I, No. 1 of the Natural History Section covered "The littoral fauna of Krusadai Island in the Gulf of Mannar, with appendices on the vertebrates and plants." This has been followed by consistently good Bulletins, dealing mostly with animal groups on Krusadai Island, not covered in the first volume.

Realising the rich potential for study offered by the coral reefs and associated flora and fauna, a Marine Biological Station was started at Krusadai Island in 1922. However, the pride of the State was the Madras Aquarium, which opened even earlier, on October 21, 1909. Situated at a strategic location on the Triplicane (Marina) Beach opposite Presidency College, it was constructed at the then princely amount of Rs. 17,604. It had been the brainchild of Mr. E. Thurston, Superintendent of the Madras Museum, but he retired before its completion. For ten years it remained in the charge of the Superintendent of the Museum, but in 1919 it was transferred to the Department of Fisheries.

The vicissitudes of the Second World War forced the Madras Aquarium to close down in 1942; it reopened after well over a decade in an attenuated form, exhibiting, mainly, a few small species of freshwater fishes.

Of an equally high quality as the Bulletins of the Madras Government Museum were those brought out by the Madras Department of Fisheries. The first *Madras Fisheries Bulletin* came out in 1905, and by 1923 there were 17 of them, covering topics ranging from oyster culture to *bêche-de-mer*.

Apart from government institutions, valuable research is also undertaken by universities. The oldest, the University of Madras established in 1857, has both Botany and Zoology Departments. The former changed its name in 1964 to become the Centre of Advanced Study in Botany. The School of Biological Sciences, of the Madurai Kamaraj University, has a Marine Science Station at Tiruchendur, near Tuticorin. The Marine Biological Station of Annamalai University, which was established at Parangipettai (Porto Novo) in 1952, became a separate department of the University in 1955 and was, in 1963, recognised as the Centre of Advanced Study in Marine Biology.

ANDAMAN AND NICOBAR ISLANDS

Marine biological studies started quite early in "the Bay Islands." It was back in 1871, that the Trustees of the Indian Museum sent Dr. J. Wood-Mason to the Andaman Islands to investigate the fauna. However, though the *R.I.M.S.S. Investigator* had many stations in the Andaman Sea, it was almost a century later, during the 3rd Five-year Plan (1961-62 to 1965-66) that a joint field expedition visited the Great Nicobar Island.

The establishment of the Andaman and Nicobar Regional Circle at Port Blair by the Botanical Survey of India in 1972, followed five years later by that of the Regional Station by the Zoological Survey of India, gave a much needed fillip to marine biological work, and its tempo picked up after this.

Many ships have carried out oceanographic work in the Indian Ocean: examples are *Challenger* (1874-75), *Gazelle* (1874-75), *Elizabeth* (1877), *Penguin* (1891), *Waterwitch* (1895), *Stork* (1897), *Valdivia* (1898-99), *Gauss* (1901-03), *Sealark* (1906), *Planet* (1906), *Howe* (1913), *Merlin* (1920), *Amiraglio Magmachi* (1924), *Ormonde* (1927), *Snellius* (1929), *Dana* (1929-30), *Discovery II* (1930-51), *Albatross* (1948), *Charcot* (1949-50), *William Scoresby* (1950), *Galathea* (1950-52), *Ob* (1955-57), *Laperouse* (1956), *Norse I* (1955-57), *Owen* (1957-58), *Atlantis* (1959) and *Vityaz* (1960).

Investigator obtained data both in the Bay of Bengal and the Arabian Sea, but the only ship which exclusively studied the Arabian Sea was *H.E.M.S. Mabahiss*, of the John Murray Expedition (1933-34), led by Lt. Col. R.B.S. Sewell. The purpose of the expedition was to study the areas west of the Laccadive and Maldive Archipelagoes, which had not been covered by *Investigator*: the ship was based at Alexandria in Egypt.

LAKSHADWEEP ISLANDS

Like the Bay Islands, a fair share of the work done by *R.I.M.S.S. Investigator* was also devoted to the Lakshadweep. Before independence, Laccadive Islands as they were then called together with Maldive Islands, were part of the British Indian Empire. After independence, while Maldive Islands became a separate new nation, the Lakshadweep-Minicoy group remained as a part of India. They then formed part of the erstwhile Madras State, but, in

November 1956, they became a Union Territory being administered from Calicut. From March 1964 the administrative capital is Kavaratti, one of the islands. Unlike the coral reefs of the Andaman Islands, which are of the fringing type, Lakshadweep and Maldive Islands are coral atolls: the islands were made by the coral animals and slowly rose above sea level.

Studies prior to independence included both the Maldives and Laccadives. The most notable piece of work on the group is the collection of papers, edited by J. Stanley Gardiner and titled "The Fauna and geography of the Maldive and Laccadive Archipelagoes." The first volume, of 471 pages was published in 1903, while Volume II, of 1,079 pages, came out in 1906.

KERALA

The present Kerala State is comprised of the erstwhile States of Travancore and Cochin and the Malabar District of the former Madras Presidency. The erstwhile University of Travancore (now Kerala University) had its own Department of Aquatic Biology and Fisheries, established in 1938 and shifted to the Aquarium in 1940. The Aquarium at Trivandrum was the second oldest in India and was the only one to be run by a university. The University's Bulletins of the Central Research Institute maintained a high standard, and are now published as Bulletins of the Department of Marine Biology and Oceanography. The University has its own research boat, *R. V. Conch*, and the Indian Ocean Biological Centre, established by UNESCO in 1963, occupies a wing of the building housing its oceanographic laboratory.

As early as the beginning of the 20th century, the Fisheries Department of the then Madras Presidency opened a marine laboratory at West Hill, Calicut on the west coast of the Presidency (now in Kerala).

The Cochin University of Science and Technology, established in 1971, had its own School of Marine Sciences. The Naval Headquarters started a Naval Physical and Oceanographical Laboratory in Cochin in 1952; in 1958, it was brought under the Defence Research and Development Organisation, and is now under the Research and Development Headquarters, Ministry of Defence. Its present activities include oceanography, acoustics, and development of electronic instrumentation. The Centre for Earth Science Studies, established by the State Government in 1978, also has bearing on subjects such as geophysics, seismology, etc.

Kerala is, at present, the headquarters of the Central Marine Fisheries Research Institute (CMFRI), which was established just before India's independence, in February 1947 at Mandapam camp in Tamil Nadu, and was later shifted to its present site. This Institute does not fall within the purview of this article and I am just mentioning it as it has been the training ground of scientists who later shifted to greener pastures. Thus, Dr. N.K. Panikkar, its second Director, was instrumental in founding the National Institute of Oceanography, while Dr. T. Jones, who succeeded him, started the Marine Biological Association of India in 1958. This Association has been doing yeoman service to the cause of marine biology, bringing out its own journal and organising symposia. The subjects of these symposia have been Scombroid fishes, Crustacea, Mollusca, Corals and coral reefs, Coastal Aquaculture, and Endangered Marine Animals and Marine Parks.

KARNATAKA

The Department of Post-graduate Studies and Research in Marine Biology, of the Karnataka University, has a marine laboratory at Kodibag, Karwar dating back to 1975, while the staff and students of the College of Fisheries at Mangalore, apart from research in marine fisheries, have also studied other marine animals.

GOA

Having been a Portuguese colony till 1962, the foremost name of a marine science organisation that is associated with Goa is the National Institute of Oceanography. The genesis of NIO is a long and interesting tale.

National Institute of Oceanography

In the 1950s, it was felt that, while the Atlantic and Pacific Oceans had been studied (from an oceanographic viewpoint), the Indian Ocean had been neglected. As this Ocean was bordered by poor, developing nations, it was beyond the financial capacity of a single country to study it. At a meeting of the SCOR (Scientific Committee on Oceanic Research) at Woods Hole, USA, in 1957, it was decided to launch an International Expedition to the Indian Ocean. This was endorsed by UNESCO.

On the Indian side, Government set up the Indian National Committee on Oceanic Research (INCOR) in 1960, under the chairmanship of Dr. D.N. Wadia, F.R.S., a leading geologist, to plan and coordinate India's programme in the International Indian Ocean Expedition (IIOE). To implement this programme, the Council of Scientific and Industrial Research (CSIR) set up the Directorate of Indian Ocean Expedition in 1962, with Dr. N.K. Panikkar as its Director. One year later, an Indian Ocean Biological Centre (IOBC) was established in Cochin to study the zooplankton collected during the IIOE.

As India did not have an oceanographic ship at that time, (*Investigator II* had stopped work in 1938), a minesweeper of the Indian Navy, *I.N.S. Kistna* was fitted for oceanographic work. Some 54 ships, belonging to 13 nations, took part in the IIOE from 1960 to 1965.

India's involvement in IIOE resulted in experienced scientific personnel trained for oceanographic work. The Government, therefore, decided to make use of the potential by establishing, in 1966, a national laboratory under CSIR, to be called the National Institute of Oceanography (NIO). It began in 1969 with its headquarters in a rented building on Miramar beach at Panjim, Goa. Its own complex came up later at Dona Paula.

After Dr. Panikkar's retirement in 1973, Dr. S.Z. Qasim, yet another former Director of CMFRI, took over as Director. Around this time, the Naval Hydrographic Office was carrying out oceanographic cruises on *I.N.S. Darshak*. In 1976, NIO got its own research vessel, *R.V. Gaveshani*. This was a 68 m, 1,900 ton hopper barge converted for oceanographic work by Garden Reach Shipbuilders at Calcutta, and capable of accommodating 19 scientists and 45 officers and crew. It was decommissioned in 1989, but was recommissioned in 1991.

The 1980s saw a spurt in oceanographic activities, the most important being the annual visits to Antarctica on chartered ships by personnel from Defence research and various civilian research institutions. NIO got another, this time highly sophisticated, oceanographic ship, *O.R.V. Sagar Kanya*, in 1983. This is a 100 m, 4,209 gross ton ship with accommodation for 32 scientists and 50 officers and crew. [Other ships connected with oceanographic work are the Oil & Natural Gas Commission's seismic vessel *Anveshak* (acquired in 1973), the Geological Survey of India's *Samudra Manthan* (1983) and a fisheries research vessel *Sagar Sampada* (1985).]

Marine sciences received a fillip in 1981 with the setting up of the Department of Ocean Development (DOD). DOD owns *O.R.V. Sagar Kanya* and has entrusted NIO to organise its scientific programmes. The result is that NIO, which started with about 50 scientists and supporting staff in 1966, now has over 630 personnel, with regional stations at Cochin, Mumbai and Waltair.

MAHARASHTRA

As with the erstwhile Madras Presidency, which had done yeoman marine studies as far back as the 19th century, the former Bombay Presidency (now split up since 1960 into Gujarat and Maharashtra) carried out excellent work on India's western coast. To understand the reason for this, one must have an idea of the natural advantages offered by this region. Why is it that marine activities have played such an important role in developing its capital, Mumbai — once a group of seven islands inhabited by fishermen and toddy-tappers? One of the main reasons for its maritime prosperity has been the superb quality of its boats and the skills of its boatbuilders. When the East India Company acquired Bombay (now Mumbai) as part of the dowry brought by the Portuguese princess Catherine of Braganza by her marriage to King Charles II, the English soon noticed that, while their men-of-war, built of sturdy oak, hardly lasted twenty years, local boats made of teak stood the ravages of time and woodborers for seventy, eighty and even a hundred years. They invited the skilled Parsee boatbuilders of Surat to come over to Bombay and settle there. (The Parsees are a minuscule community of Zoroastrians which fled from Iran over 1,360 years ago to avoid persecution when the Muslims conquered Persia). *H.M.S. Trincomalee* (now called *Foudroyant*), built by Maneckji Lavji Wadia, a Parsee master shipbuilder, using teak from the Dangs forest of Gujarat, is the oldest ship in the world still afloat and in active service. Lord Nelson (of the naval Battle of Trafalgar fame) visited Bombay in 1775, and his brother, serving in the Indian Navy, was murdered in Bombay; his mortal remains lie in the cemetery on Queen's Road, now converted into the S.K. Patil Garden.

While the fishermen from south India used primitive catamarans made by lashing a few planks of wood, the fishing boats of Bombay Presidency were of such superb design that an engine could be fitted on to them without any structural modification.

Excellent docking facilities and a safe harbour are two other reasons for Bombay's popularity. The Marine Survey vessel *R.I.M.S.S. Investigator* had its base at Bombay, and passed the rigorous monsoon months here. *H.E.M.S. Mabahiss* of the John Murray Expedition led by Lt. Col. R.B.S. Sewell (1933-34) docked at Bombay on December 13, 1993. Later, during the International Indian Ocean Expedition (1960-65), Bombay was the base for the U.S. oceanographic vessel *Anton Bruun*, which made nine cruises in the Indian Ocean. (At the end of the IIOE, the U.S. Government offered *Anton Bruun* free of charge, as a gift, to India, but this offer was reluctantly rejected as the Government of India felt that it could not afford its running costs, amounting to Rs. 100,000 per day. *O.R.V. Sagar Kanya*, incidentally, requires Rs. 200,000 per day as its running costs.)

If one goes by genealogy, the oldest institute in this State, known for its high quality of field studies, is the Bombay Natural History Society. Its role in marine sciences is, however, a low key one, as its forte is mammalogy and ornithology, but one cannot do justice without at least referring to it. The Society's collections are now considered a protected national heritage and, especially as birds and mammals go, rival those of the Zoological Survey of India. Part of the Society's collections was shifted to the Prince of Wales Museum created in 1921. The Society also brings out its own Journal, begun in 1886 and catering to field biology and natural history. It also has a popular magazine named *Hornbill*.

Equally as popular as the city's museum is the Taraporevala Aquarium on Marine Drive. It has had a long wait before a single person's dream bore fruit. This person was Dr. Sam B. Setna, who tirelessly cajoled and needled the authorities until the bureaucracy was moved by his pleas.

In 1931 and 1932, he went as Fishery Officer to the Andaman Islands, where he was dazzled by the fascinating coral reefs and associated marine life. In 1933, he became an officer in the Fisheries Section of the Industries Department of the Government of Bombay. A full-fledged

Department of Fisheries was set up in 1945 and he became the first Director of Fisheries, a position he was to hold till his retirement in 1955.

The first proposal for the establishment of a public aquarium in Bombay was made in 1912 by Mr. W.S. Millard, the Honorary Secretary of the Bombay Natural History Society. He was deputed by the Government of Bombay to visit Madras and report to Government on the Aquarium there. Nothing came of it and Dr. Setna, then on the staff of the Royal Institute of Science, revived the proposal in 1930. He also wrote a series of articles in the local newspaper columns for setting up a marine biological station which could serve as a Mecca for those aspiring to specialise in the study of marine life.

In the meantime, in 1926, the University of Bombay had appointed a seven member committee to consider the desirability of establishing a marine biological station at Bombay. At the joint session of the Zoology and Botany Section of the Indian Science Congress at Patna in 1933, under the presidentship of Lt. Col. R.B.S. Sewell, a resolution was unanimously passed, advocating the establishment of a marine biological station. This proposal was also endorsed by Dr. J. Stanley Gardiner, Head of the Zoological Laboratory at Cambridge, who had earlier worked on the fauna of Maldive and Laccadive Islands. The question of having an Aquarium was again opened afresh in the early 1930s by Sir Reginald Spence, Honorary Secretary of the Bombay Natural History Society. Finally, the munificence of Mr. Vicaji D.B. Taraporevala and his wife Putlibai, in the form of a joint donation of Rs. 200,000 in 1945, enabled the establishment of a public aquarium and a marine biological station attached to it. Subsequently, they donated a further amount of Rs. 100,000 towards the setting up of a library (called the Shrimati Putlibai Taraporevala Library) as a part of the marine biological station. The Aquarium opened on May 27, 1951.

The Taraporevala Marine Biological Station also had its own 15-metre research boat *Mysis*. Until 1972, the Research Station was a part of the State Fisheries Department and was affiliated to the University of Bombay. It was then taken over, first by the Mahatma Phule Agriculture University, and now, forms part of the Fisheries wing of the Konkan Agriculture University.

The State Department of Fisheries, realising that marine research activities were concentrated at Bombay, set up a second marine biological station at Ratnagiri in the south of Bombay State. This, too, has been taken over by the Konkan Agriculture University.

As in other States, there are many institutions primarily oriented towards fishery, but also playing their part in marine sciences. Apart from the western region office of the National Institute of Oceanography, there are in Bombay the Central Institute of Fisheries Education (CIFE), Fishery Survey of India (earlier named Exploratory Fisheries Project, and still earlier known as Deep-Sea Fishing Station), Regional Research Station of the Central Marine Fisheries Research Institute (CMFRI), and the local chapter of the Indian National Science Academy (earlier called the National Institute of Science, and which brings out the *Indian Journal of Marine Sciences*).

GUJARAT

Besides the offshore Lakshadweep group of islands, the Gulf of Kachchh (=Kutch) near Port Okha is the only region on the west coast of India having abundant coral reefs. The rich flora and fauna associated with these coral reefs has attracted the attention of marine biologists for a long time.

A good deal of work on the algal (seaweed) flora of the former Bombay Presidency was done at Karachi (Sind was then a part of Bombay Presidency) as early as 1859 by W.J.S. Pullen, followed by F. Boergesen between 1930 and 1938. The fortuitous circumstances of Okhamandal being a part of the former Baroda State, ruled by the enlightened Gaekwads (rajas), led to the most outstanding study of the region. At the behest of Gaekwad Sayajirao, James Hornell, F.L.S., then serving in the Bureau of Fisheries, Madras and earlier Marine Biologist to the Government of Ceylon made an in-depth study of the region from December 1905 to January 1906. The results of this study are embodied in the MARINE ZOOLOGY OF OKHAMANDAL, the first volume of which was published by William Norgate, London in 1909, followed by Part II in 1916.

This has resulted in the (rather belated) establishment of the Gujarat Aquatic Sciences Research Station at Okha in the early 1970s.

Notable work on the State's flora was also done at the Central Salt and Marine Chemicals Research Institute (CSMCRI), located at Bhavnagar, in the 1960s. The Institute was established as a laboratory of CSIR in 1954 (when Bhavnagar was in the erstwhile Saurashtra State) and has a branch at Okha. For a detailed review of work done on Indian seaweeds, one may refer to J.N. Misra's paper titled "Phaeophyceae in India," an ICAR publication of 1966.

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CONTRIBUTIONS TO THE BIOLOGY OF THE QUEENLESS PONERINE ANT *DIACAMMA CEYLONENSE* EMERY (FORMICIDAE)

(*With five text-figures*)

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All ants are generally classified as highly eusocial. However, there are some 100 species of ants belonging to the morphologically primitive subfamily Ponerinae, which lack a morphologically differentiated queen. One or a small number of mated workers (gamergates) function as queens, i.e. they produce male as well as female offspring. Such ant species are of great interest as they provide unique opportunities to understand the causes and consequences of queenlessness. This is the first report of a long-term field study we have initiated on a large population of the queenless ponerine ant, *Diacamma ceylonense* Emery, on the campus of the Indian Institute of Science, Bangalore. Data are provided on the numbers of colonies present during a 213-week period, from which the probable time of colonisation of the site by *D. ceylonense* is suggested. Twenty-six entire colonies were excavated to study the adult and brood composition. While some colonies did not appear to have a gamergate at the time of excavation, others had only one gamergate per colony. Only the gamergate was mated and had well developed ovaries, while all the workers were unmated and had undeveloped ovaries. Excavated colonies had an average of 230 adult females, 2 males and 80 items of brood. The gamergates were indistinguishable from their workers in body size but there was significant variation in the size of workers between colonies. On an average, colonies employed 24% of their workers outside the nest for foraging and other duties. The relative constancy of this proportion permits estimation of total colony size by merely estimating the number of extranidal workers and thus without having to excavate the nests. In the five colonies studied, foragers spent an average of 9 to 23 days of their lives in performing foraging duties. Most foragers remained faithful to one or a narrow range of compass directions, although such directional preferences of all of them put together permitted colonies to exploit resources in all directions.

INTRODUCTION

Eusocial insects are defined as those insects whose colony members exhibit overlap of generations, cooperative brood care and reproductive caste differentiation into a queen caste and a worker caste. Highly eusocial species are those in which the queen and worker castes are morphologically differentiated (Wilson 1971). In this scale of social evolution, all ants are generally classified as highly eusocial (Hölldobler and Wilson 1990, Bourke and Franks 1995). However, some 100 species of ants, belonging to the morphologically primitive subfamily Ponerinae, lack a morphologically distinguishable queen. Their colonies consist only of workers (in addition to males of course), one or a few of whom are mated and take on the function of queens, i.e. production of male and female offspring. These mated, reproducing workers are termed gamergates (Peeters 1991). Queenless ants are of great interest for several reasons: (1) They provide an opportunity to understand the conditions under which the queen caste may be lost. (2) In the absence of winged queens, new colonies have to

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be necessarily founded by walking gamergates, which must result in a rather unusual population genetic structure. (3) They can be used as model systems to understand how one or a small number of individuals can establish and maintain reproductive monopoly among a group of identical, or nearly identical, individuals. This is a problem that has been extensively investigated with bees and wasps (see Gadagkar 2001 and references therein) but because queenlessness in ponerine ants is evolutionarily derived from the queenright condition (Baroni Urbani *et al.* 1992), a new perspective is expected from a study of these ants.

In this context, the genus *Diacamma* represents a most fascinating example. In *Diacamma*, all females eclose with a pair of club-like thoracic appendages called gemmae. The gamergate mutilates all workers who eclose after her, by clipping their gemmae. Such mutilation results in poorly understood neurological changes in the victims, making them incapable of sexual calling and mating. This unique mechanism by which the gamergate maintains her reproductive monopoly seems to have a built-in mechanism to ensure that a colony does not necessarily die if its gamergate dies. Mutilated workers do not mutilate others so that, upon the death of a gamergate, the next individual to eclose retains her gemmae, mutilates all those that eclose after her and takes over as the next gamergate of the colony (Fukumoto *et al.* 1989, Peeters and Higashi 1989). While this description fits all other species of *Diacamma* examined so far, there does appear to be an exception. There is at least one species in which the gamergate seems to be capable of maintaining reproductive monopoly without mutilating her workers. This species, which was first found at the foot of the Nilgiri hills, and mistakenly identified as *Diacamma vagans* Smith (Peeters *et al.* 1992), is yet to be described. We therefore refer to it here as *Diacamma* sp. from Nilgiri. *Diacamma* sp. from Nilgiri is morphologically very similar to *Diacamma ceylonense* Emery, which is abundantly distributed in and around Bangalore. There is a large population of *D. ceylonense* in the so-called Jubilee Garden in the campus of the Indian Institute of Science, Bangalore (13° 00' N 77° 32' E). Such an easily accessible population facilitates observation of colonies in their natural habitats. Most previous work on *Diacamma*, and indeed on most ponerine ants, has been largely restricted to observation in artificial nests in the laboratory, of ants removed far from their natural habitat.

For all these reasons, we have initiated a long-term study of the population of *D. ceylonense* in the Jubilee Garden of the Indian Institute of Science, Bangalore. This is the first report of this ongoing study.

MATERIAL AND METHODS

This study was conducted in the Jubilee Garden, Indian Institute of Science, Bangalore. The site is a plantation of *Acacia auriculiformis*, with a few individuals of *Polyalthia longifolia, Tamarindus indica* and *Ficus* sp. The area (about two hectares) was divided into 60 line transects. Initially, an extensive search was conducted to locate the nests of *D. ceylonense*. All nests were marked with sequentially numbered aluminium tags and the tree nearest to each nest was marked with red paint. Every Monday, the nests were monitored for activity and for the occurrence of males. Nests that appeared to be abandoned were checked by inserting a stick inside the nest entrance and waiting for the appearance of workers. In addition, such nests were also monitored for activity during the subsequent 4-5 weeks, before confirming them as abandoned. On the first Monday and Tuesday of every month, the entire study site was searched systematically to record any newly initiated nests. Data thus obtained, during 213 weeks, on the numbers of nests, numbers of newly initiated nests, abandoned nests and number of males, were analysed in relation to abiotic factors such as maximum and minimum temperatures and total rainfall using the Kendall's correlation coefficient. Climatic data were obtained from the India Meteorological Station, Bangalore. As there was a monotonic increase in the number of nests during the first 120 weeks of study, a linear regression model was fitted to these data which was then used to predict the probable time of colonisation of Jubilee Garden by *Diacamma ceylonense*.

Twenty-six colonies with all individuals and brood were collected from within the Indian Institute of Science campus, but outside the Jubilee Garden. Nest characteristics such as height of the mound, number of brood chambers, depth of the nest and commensals encountered, were recorded for all these nests. Head width and alitrunk length of all individuals were measured in 21 of these colonies. Data on head width and alitrunk length were subjected to one-way analysis of variance to partition variance within and between colonies. In the nine colonies that had a gamergate, one-sample t-tests were performed to compare each gamergate with her workers. In 15 of these 21 colonies (including the nine that had a gamergate), the numbers of mature eggs, width and length of proximal oocytes and the presence (or absence) of sperm in the spermatheca, were recorded for all individuals by dissecting their gaster.

Five other colonies were chosen for observation of the extranidal behaviours. Four of these colonies were observed for four weeks each while one was observed for 55 weeks. Each observation session was of 4-hour duration and was conducted either in the morning (0600 to 1000 hrs), midday (1000 to 1400 hrs) or afternoon (1400 to 1800 hrs). One each of the morning, midday and afternoon sessions were completed in each week, thus yielding 12 hours of data per week, per nest. All new workers seen outside the nest were uniquely marked with quick-drying coloured paint on the thorax or abdomen, starting two weeks before the commencement of observations and continuing throughout the period of observation. All extranidal behaviours visible to the observer, positioned near the nest mound, were recorded. The 852 hours of data thus collected, were used to compute the number of extranidal ants active per day, the number of days for which different ants were active, and the rate per hour at which they performed extranidal activities. When the ants left the vicinity of the nest mound, the compass direction in which they departed was recorded in eight discrete directions namely North, Northeast, East, Southeast, South, Southwest, West and Northwest. When the foragers returned, what they brought back (food, building material or nothing) was noted. The proportion of successful and unsuccessful trips made by foragers who had made at least three trips were then computed and compared. A successful trip was defined as the act of returning to the nest with either food or building material. An unsuccessful foraging trip was one in which the ants returned with neither food nor building material. Data on foraging directions of all active foragers were subjected to Rayleigh's test (Batschelet 1981) of randomness to determine the degree of randomness in the foraging paths, both for individual ants as well as for colonies as a whole.

Another eleven colonies were excavated in an attempt to predict the colony size from the numbers of ants engaged in extranidal tasks. Over a period of three days, all ants seen outside the nest were marked. At least two persons spent 3 hours and 30 minutes each, per day (30 minutes at the beginning of every hour from 0600 hrs-1800 hrs) for three consecutive days, marking the ants. Pilot experiments had indicated that this effort was more than adequate to mark all extranidal ants. On the fourth day the nest was excavated to determine the colony size (these nests were then used for other experiments not reported here) so that the relationship between the number of extranidal ants and the total colony size could be ascertained.

RESULTS AND DISCUSSION

Diacamma ceylonense nests were found to occur quite commonly in the study area. The nests are subterranean, with a distinct mound at the entry of the nest. The mounds are often decorated with dry twigs, leaves, insect and spider exuviae, and occasionally, bird feathers. Moffett (1985) observed that these decorations are used to harvest dewdrops, which the ants drink in the mornings. The excavated nests contained 230.5 ±108.6 adult female ants, 2.3 ±5.3 males, 18.5 ±19.4 eggs, 22.6 ±18.7 larvae and 40.0 ±36.6 pupae. The nests were 63.9 ± 20.6 cm deep under the ground with 4.1 ±1.2 brood chambers and the mounds were 3.2 ±4.1 cm above the ground (Table 1). Males were usually found in the first chamber, closest to the entrance. The next 2-3 chambers had brood and the last chamber at the bottom contained refuse. We often found cockroaches, isopods, crickets, pseudoscorpions, bagworms, grubs, earthworms and a few other ant species in the nests; we presume that these were commensals (Table 2). Nine out of the twenty-one colonies excavated, seemed to lack a gamergate; the possibility that the gamergate was lost during excavation seems unlikely but cannot, of course, be entirely ruled out. The remaining 12 colonies invariably had only one gamergate each. In two nests, one or two individuals other than the gamergate also had gemmae, but only on one side of their thorax; perhaps their mutilation was not yet complete. Of the 15 colonies used for dissection, 9 had one gamergate each, while the remaining 6 colonies did not have a gamergate. The number of mature eggs in the gamergates ranged from 0-24 with a mean of 8.78 ±10.28 eggs. None of the workers had developed ovaries and none of them were mated in any of the colonies, including those without a gamergate (Table 1). Thus *D. ceylonense* colonies are monogynous and recent molecular studies suggest that they are also monoandrous but with some serial polygyny (gamergate turnover) (Gopinath 2002).

Table 2: Co-inhabitants observed in *Diacamma ceylonense* nests

Commensal	No. of nests in which observed
Cockroaches	12
Crickets	11
Pseudoscorpions	9
Bagworms	3
Grubs	1
Earthworms	1
Isopods	14
Other ant species	1

For both head width and alitrunk length, there was a significant added variance between colonies. In the case of head width, this added variance between colonies was significantly higher than the variance within colonies, while in the case of alitrunk length, this variance was significantly less than the variance within colonies (Table 3). Variance between colonies is

Table 3: One-way analysis of variance of head width and alitrunk length of individuals of *Diacamma ceylonense* from 21 colonies

	Source	DF	SS	MS	F	p
Head width[a]	Among colonies	20	1811.07	90.55	791.42	0.001
	Within colonies	4731	541.31	0.11		
	Total	4751	2352.38			
Alitrunk length[b]	Among colonies	20	1151.20	57.96	94.61	0.001
	Within Colonies	4683	2849.00	0.61		
	Total	4703	4000.19			

[a] Variance between colonies significantly higher than variance within colonies

[b] Variance between colonies significantly lesser than variance within colonies

Table 1: Colony composition and body measurements of the individuals in *Diacamma ceylonense*

Date of collection	Colony code	No.of females	No.of males	No.of eggs	No.of larvae	No.of pupae	Depth of nest (cm)	Height of mound (cm)	No.of brood chambers	Head width[a] (mm)	Alitrunk length[a] (mm)	No. of mature eggs[b]	Width proximal oocyte (mm)	Length of proximal oocyte (mm)
25.11.93	D-1	292[c]	0	[d]	11	15	50	0	4	—	—	—	—	—
25.01.94	1	341	0	0	13	15	50	6	3	1.99 ±0.05	3.91 ±0.14	—	—	—
24.02.94	2	499[e]	0	0	23	78	150	0	5	2.29 ±0.03	4.51 ±0.10	—	—	—
31.03.94	3	319	3	[d]	51	110	75	0	3	2.26 ±0.09	4.54 ±0.16	—	—	—
27.04.94	4	140[e]	0	28	20	30	50	0	2	2.02 ±0.06	4.14 ±0.15	—	—	—
24.05.94	5	158	8	8	29	15	65	0	4	2.02 ±0.06	4.10 ±0.14	—	—	—
28.06.94	6	420[e]	0	36	55	103	55	0	4	2.00 ±0.05	4.14 ±0.16	—	—	—
28.07.94	7	220[c]	0	42	51	45	65	5	5	—	—	—	—	—
23.08.94	D-2	184[c]	0	14	13	3	65	0	4	—	—	—	—	—
31.08.94	8	251	0	46	31	35	45	7	3	2.03 ±0.07	3.97 ±0.20	0	0.31 ±0.06	0.98 ±0.39
28.09.94	9	286	1	66	66	64	50	0	6	2.06 ±0.08	4.10 ±0.16	13	0.37 ±0.13	1.03 ±0.38
27.10.94	10	91	0	0	8	18	70	0	4	2.01 ±0.06	4.07 ±0.18	0	0.43 ±0.17	0.95 ±0.49
15.11.94	11	161	0	33	0	12	60	0	3	2.00 ±0.05	4.06 ±0.16	0	0.29 ±0.04	0.73 ±0.29
06.12.94	12	138[e]	0	0	0	0	60	10	5	2.05 ±0.07	4.20 ±0.15	—	—	—
18.01.95	13	18[e]	0	0	0	0	60	10	2	2.10 ±0.07	4.25 ±0.16	—	—	—
07.02.95	14	250	0	3	1	0	50	5	5	2.07 ±4.29	4.29 ±0.14	3	0.38 ±0.04	1.31 ±0.14
08.03.95	15	293	13	33	33	55	85	0	5	2.04 ±0.07	4.23 ±0.17	16	0.46 ±0.03	1.4 ±0.05
05.04.95	16	180[e]	0	35	10	23	80	0	7	2.02 ±0.08	4.18 ±0.14	—	—	—
17.05.95	17	131	1	24	21	38	60	0	3	2.03 ±0.08	4.15 ±0.17	24	0.43 ±0.08	1.27 ±0.25
16.06.95	18	297	10	44	26	75	65	0	4	2.06 ±0.08	4.26 ±0.13	23	0.4 ±0.06	1.33 ±0.21
13.07.95	19	269	22	0	11	130	60	0	5	2.06 ±0.08	4.32 ±0.23	0	0.63 ±0.08	0.25 ±0.04
25.07.95	D-3	237[c]	0	0	9	11	50	10	5	—	—	—	—	—
23.08.95	20	200[e]	0	9	35	49	40	8	4	2.00 ±0.05	4.21 ±0.14	—	—	—
13.09.95	21	312[e]	0	11	34	53	65	5	4	2.06 ±4.28	4.28 ±0.17	—	—	—
15.09.95	D-4	262[c]	0	11	36	64	70	8	5	—	—	—	—	—
27.10.95	22	45[e]	1	0	0	0	65	10	2	2.06 ±0.08	4.32 ±0.14	—	—	—
MEAN		230.5 ±108.6	2.3 ±5.3	18.5 ±19.4	22.6 ±18.7	40.0 ±36.6	63.9 ±20.6	3.2 ±4.1	4.1 ±1.2	2.04 ±0.07 (n=4751)	4.16 ±0.21 (n=4703)	8.8 ±10.3		

[a] Up to 9% of the individuals were not used for head width and alitrunk length measurements in some colonies; [b] mature eggs - those which were about to reach the main duct; [c] Body measurements not done; [d] Eggs not counted; [e] Colony without gamergate; All gamergates dissected were found to have sperms in the spermatheca.

likely to have a genetic basis and variance within colonies, a nutritional basis. As expected from the fact that the gamergate is simply an unmutilated worker, in 17 out of 18 tests (9 colonies, each tested for head width and alitrunk length), the gamergate was not significantly different in body size as compared to the workers in the colony (one sample t-test; Table 3).

The number of active nests steadily increased from the commencement of this study (December 1993) up until 120 weeks. After that the number of active nests decreased to an extent (Fig. 1a). In our 213 weeks of study, we recorded a total of 117 nests, active at one time or another. Although new nests were initiated and abandoned throughout the study period, initiations usually outnumbered abandonings during the first 175 weeks, while abandonings outnumbered initiations during the next 38 weeks (Fig. 1b,c). Twenty-one out of 117 nests were active throughout the 213 weeks of observations. Given that they were already present at the beginning of the study, they must have been older than 213 weeks. Males were few in number but were recorded more or less throughout the year (Fig. 1d). Climatic data are depicted in Fig. 1e. There was a positive correlation between minimum temperature and number of nests initiated ($\tau = 0.26$ at $p<0.008$) and abandoned ($\tau = 0.38$, at $p<0.0001$). There was also a positive correlation between rainfall and number of nests initiated ($\tau = 0.43$ at $p<<0.01$) and abandoned ($\tau = 0.39$, at $p<0.0001$) and number of males ($\tau = 0.29$, at $p<0.005$). Maximum temperature showed no such correlation.

Since the number of nests increased steadily during the first 120 weeks, a linear regression model was fitted to the data (Fig. 2). The model is highly significant. Extrapolating backwards in time, using the slope and its 95% confidence interval, we may hypothesize that the Jubilee Garden was colonised by *D. ceylonense* some 85 to 113 weeks before the beginning of the study, i.e. between September 1991 and May 1992 (Fig. 2).

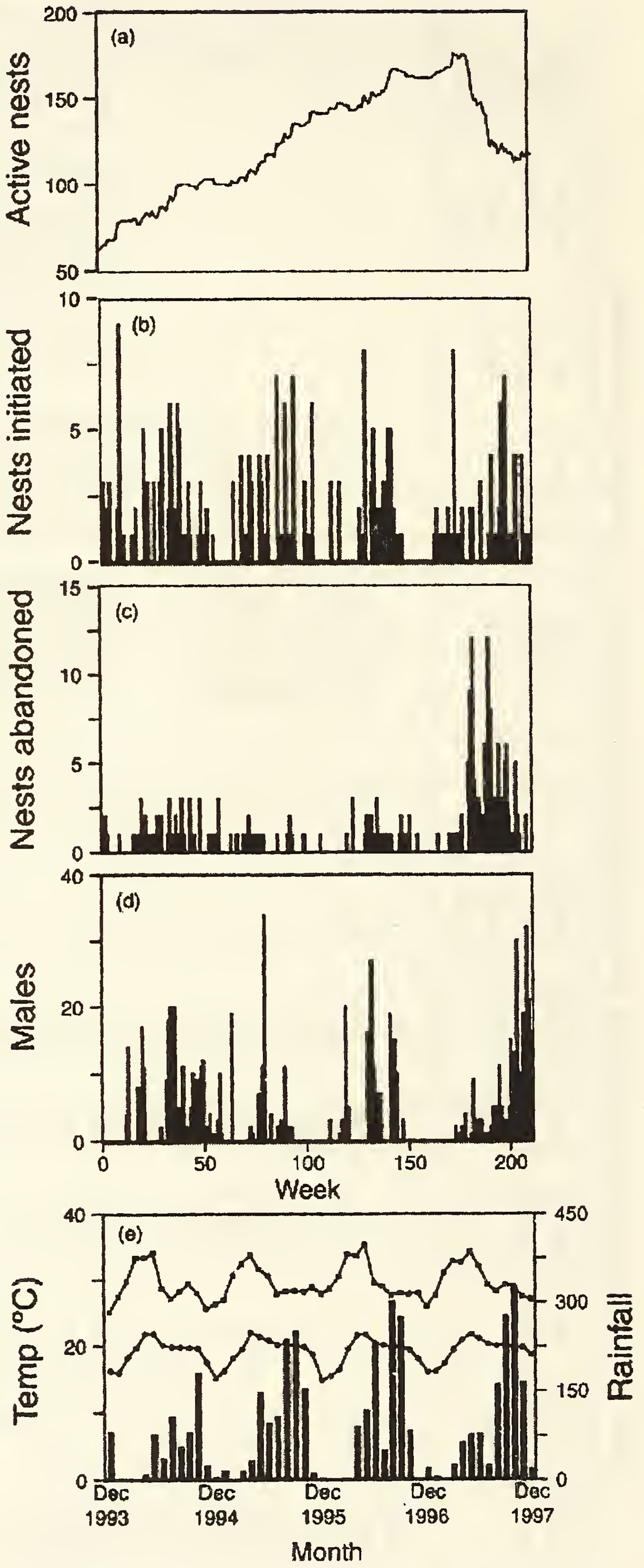


Fig. 1: The number of (a) active nests, (b) nests initiated, (c) nest abandoned, (d) males and (e) mean monthly rainfall (bars), mean monthly maximum temperature (upper line) and mean monthly minimum temperature (lower line), during the 213 weeks of census of the Jubilee Garden population of *Diacamma ceylonense*

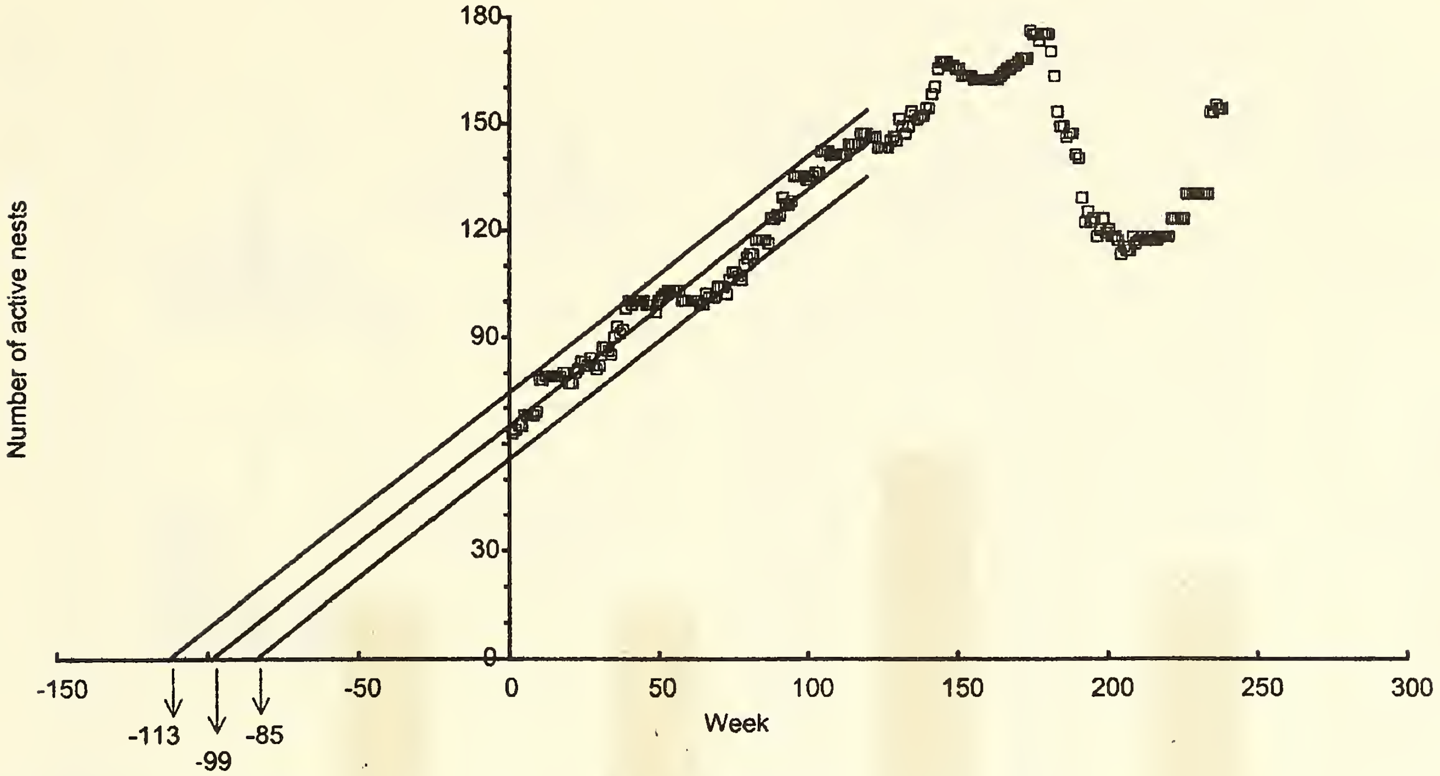


Fig. 2: Number of active nests from the 120-week data was used to fit a linear regression model which was extrapolated backwards using the slope and its 95% confidence intervals, to estimate the probable time of colonisation of Jubilee Garden by *Diacamma ceylonense*

Diacamma ceylonense workers are individual, diurnal foragers with directional fidelity within a narrow range of directions (as seen from our observations given below). Their major food consisted of termites, although bugs, cockroaches, grasshoppers, crickets, spiders and other species of ants were also observed being brought to the nest on some occasions. Prey, however large, was never retrieved in groups, but there was some cooperation among the workers near the nest to manoeuvre it through the nest entrance. Foraging continued for most of the day on colder days, but was restricted to the mornings and evenings only, on warmer days. Foraging was suspended during heavy rains although some extranidal tasks like nest cleaning and shifting of materials around the nest increased soon after rainfall. On finding an item of prey, the forager paralysed it by stinging and returned with it to the nest quickly and in a short, more linear path as compared to the often long-winding path it had followed during its outward journey. When a termite nest or trail was discovered, the successful forager made repeated trips to the same source.

The mean number of active individuals seen outside the nest during any 4-hour observation session varied from about 6 to 32 and the mean foraging life span of workers ranged from 9 to 23 days (Table 4). Foraging was the most frequently performed extranidal activity. In four out of five

Table 4: Number of active animals per observation session, and foraging life span in five colonies

Nests	No. of sessions & No. of days observed	No. of active animals/session[a] Mean ±SD (Range)	Foraging life span in days Mean ±SD (Range)
071	165 sessions; 385 days	6.7 ±3.6 (1-17)	23.3 ±22.2 (1-154)
025	12 sessions; 26 days	17.2 ±2.2 (11-21)	13.2 ±10.2 (2-26)
056	12 sessions; 27 days	32.3 ±8.0 (22-51)	9.0 ±7.6 (2-27)
0117	12 sessions; 26 days	12.9 ±3.7 (5-18)	12.9 ±8.7 (2-26)
0134	12 sessions; 23 days	16.2 ±5.5 (4-22)	15.5 ±6.1 (2-23)

[a]1 session = 4 hours

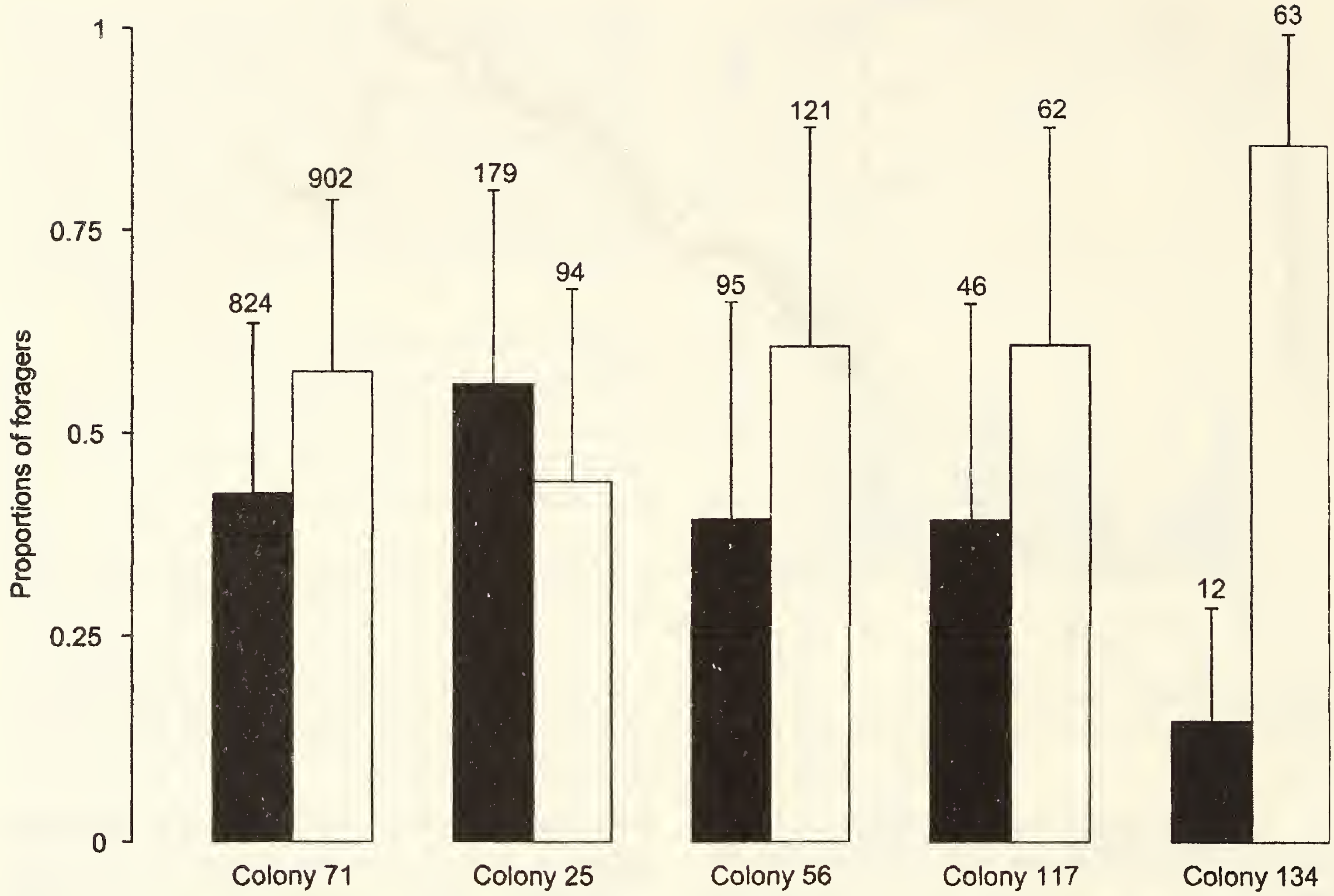
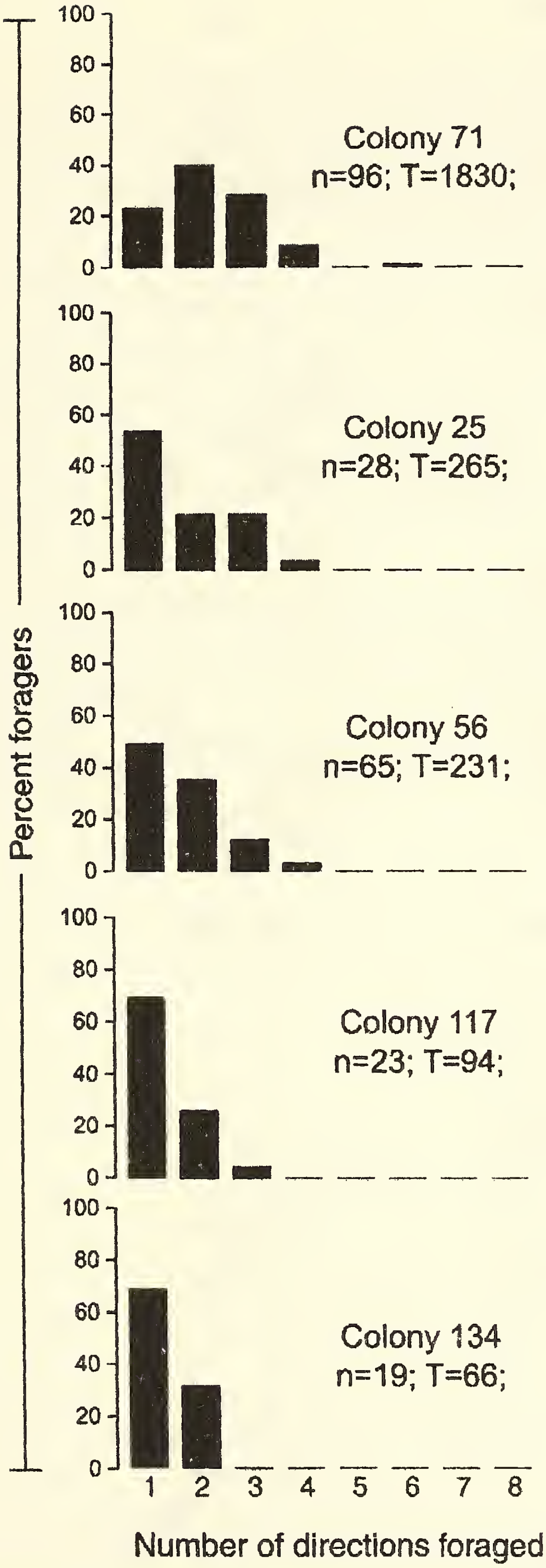


Fig. 3: Proportions of successful (shaded bars) and unsuccessful (blank bars) trips made by foragers in five colonies (numbers above bars are the numbers of successful/unsuccessful trips)

colonies (Fig. 3; Mann Whitney U test; Colony 71, 56 and 134 at $p<0.001$, and Colony 117 at $p<0.05$), the number of successful foraging trips was significantly less than the number of unsuccessful trips. In one colony (Fig. 3, Colony 25), foragers were somewhat more successful in retrieving prey items, but the number of successful and unsuccessful trips did not differ significantly from each other (Mann Whitney U test, $p>0.05$). Foragers who had made at least three trips were used for this analysis. The proportions of successful and unsuccessful trips were computed for each worker and then averaged across workers in each colony.

Many foragers seemed to be faithful to certain foraging directions (Fig. 4), although the colony itself seemed to have foragers covering all directions. Rayleigh's test of randomness confirms that in all five colonies studied, individual foragers were non-random with respect to the directions in which they made foraging trips, but that the colony as a whole (with all its foragers put together) was random in this regard. In each colony, even the most random forager was less so than the colony as a whole (according to Rayleigh's test of randomness, $p<0.05$, see Fig. 5). The mechanism by which the foragers achieve such collective randomness, in spite of individual non-randomness, remains to be investigated.

Experiments in which all the ants seen outside the nests were marked before nest excavation demonstrate that the number of ants seen outside the nest is a reasonably constant proportion of the total colony (24.39% ±9.63%) (Table 5). This information can be used to approximately infer colony size without necessarily having to excavate nests. Besides helping to avoid unnecessary excavation of nests,



n = number of foragers observed
T = total number of trips observed

Fig. 4: Frequency distribution of numbers of foragers who foraged in different numbers of direction in five colonies

Table 5: Colony size and percentage of extranidal ants

Colony code	No. of extranidal ants marked	Colony size	Percentage of foragers
DC28	69	457	15.10
DC29	89	376	23.67
DC30	135	593	22.77
DC31	23	192	11.98
DC42	23	121	19.00
DC47	47	145	32.41
DC52	47	271	17.34
DC53	24	137	17.51
DC64	60	145	41.38
DC65	39	103	37.86
DC66	12	41	29.26
Mean ±SD	51.6 ±35.9	234.6 ±171.6	24.39 ±9.63

the proportion of foragers is in itself a useful parameter in many kinds of studies (see for e.g. André *et al.* 2001, Gopinath 2002). Investigations to determine intra-colony genetic relatedness using microsatellite markers, population genetic structure using both nuclear and mitochondrial markers and the mechanism of mutilation of the gemmae are in progress and would form the subjects of future publications.

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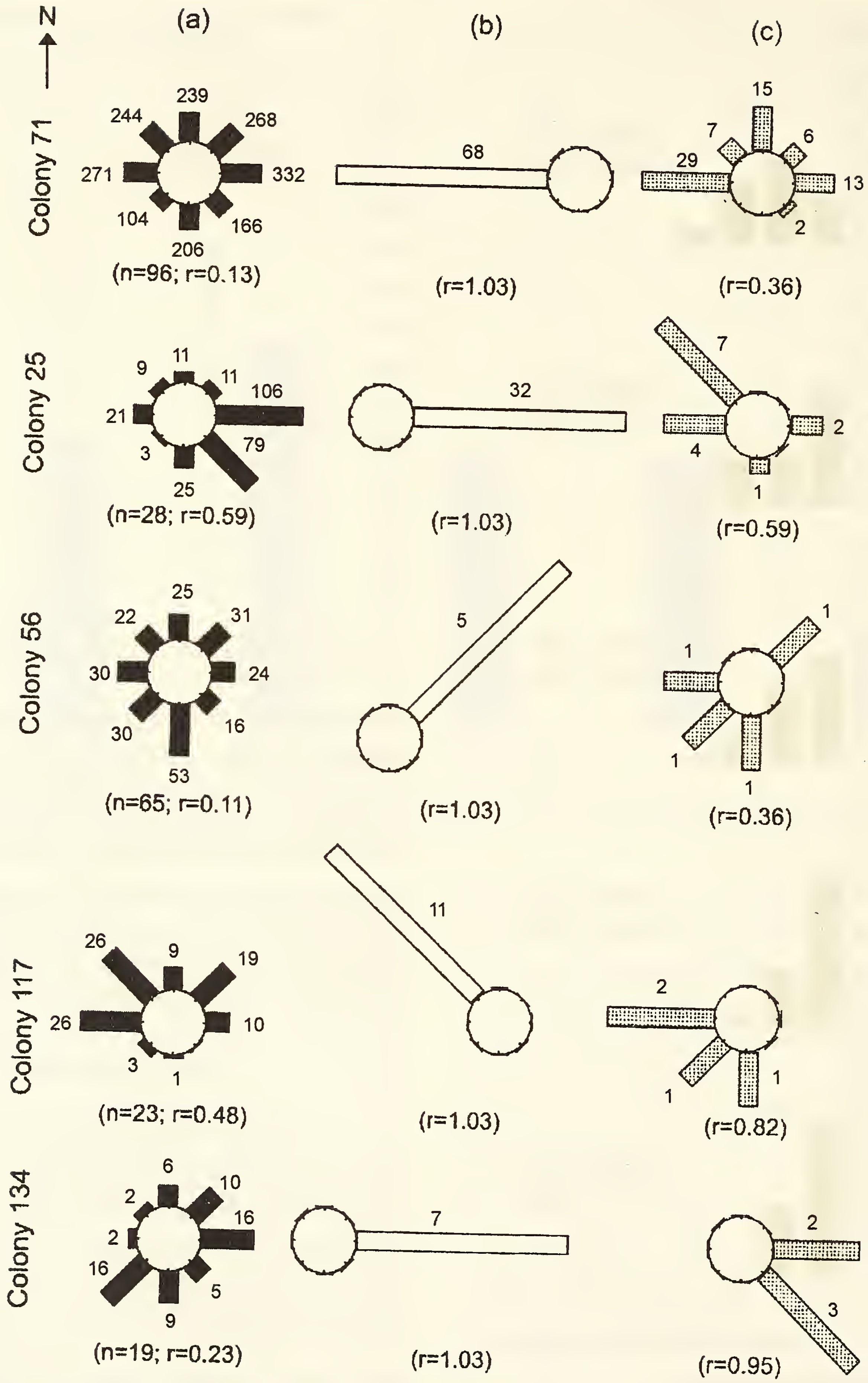

n = no. of foragers for the colony as a whole; r = randomness

Bars are proportions of number of trips made by forager(s) in different directions. Values beside each bar indicate the number of trips made by one or more foragers (in a) and one forager (in b and c).

Fig. 5: Foraging direction for (a) colony as a whole, (b) the most non-random forager and (c) for the relatively most random forager, in the five colonies studied.

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MALARIA IN INDIA — IS AN ECOFRIENDLY SOLUTION POSSIBLE?

RACHEL REUBEN[1]

Key words: Malaria, mosquitoes, *Anopheles*, malaria control, DDT, synthetic pyrethroids, insecticide treated bed-nets

Malaria control is complicated by the existence of vector species, sometimes morphologically indistinguishable, but having very different ecology and behaviour. Early attempts to control malaria by eliminating breeding met with mixed success. In Mumbai city, however, malaria transmission was completely eliminated for many years using simple anti-larval measures. The advent of residual spraying with DDT led to a dramatic reduction in malaria all over the country, but development of resistance, together with administrative problems, resulted in resurgence. Though the cases have now levelled off, numbers are still too high for complacency, and the proportion of *falciparum* cases is on the rise. More potent than DDT and far less damaging to the environment are the synthetic pyrethroids. Pyrethroid-treated bed-nets have been particularly successful, reducing malaria incidence significantly in a variety of rural situations. The amount of insecticide used is very small in comparison with house spraying, making the method cost-effective. This technology, now undergoing large-scale trials, promises to be the main plank of the malaria control strategy.

INTRODUCTION

Lizards, birds, rodents and primates, all harbour various species of the protozoan parasite *Plasmodium*, which cause malaria and are transmitted to vertebrate hosts by mosquitoes. *Plasmodium* species are often group-specific; the species found among primates are, naturally, of most interest to us. Four species cause disease in man, *P. vivax, P. falciparum, P. malariae* and *P. ovale*, of which only the first two are common. Several species are found in non-human primates, including *P. inui* in *Macaca radiata* in the Nilgiri foothills. None of these infect man, and there is only one monkey, the owl monkey *Aotus trivirgatus* of South America, which can be infected experimentally with human malaria. Interestingly, however, *P. rodhaini* of chimpanzees is morphologically identical with *P. malariae* of man (Bruce-Chwatt 1980), which shows that when the hominids split off from chimpanzee stock in Africa around 7-8 million years ago, the association with malaria was already there. New and exclusively human species must have evolved along with the hominids. Mosquitoes have, of course, been around for very much longer, and fossil mosquitoes have been found in 30 million year old geological strata.

Malaria is a disease which has caused tremendous suffering, and social and economic losses to mankind through the ages. It still remains one of the leading causes of sickness and death in the developing world, causing 300-500 million cases and 1.5 to 2.7 million deaths per year (WHO sources). The early symptoms of malaria are well known: intermittent high fever, accompanied by chills and violent shivering. Malaria caused by *P. vivax* is very debilitating, with the patient suffering a series of relapses if not treated, but it is rarely life threatening. *P. falciparum* malaria, on the other hand, if misdiagnosed or untreated, can result in cerebral malaria, leading to death. The patient becomes comatose and may also develop renal haemorrhages and other complications. Pregnant women and children are the most vulnerable to anaemia caused by malaria. In areas of high malaria transmission some degree of immunity develops, and unhealthy children with big bellies and large spleens used to be a common sight in the tea gardens of Assam.

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MOSQUITOES AND MALARIA

It was Sir Ronald Ross who first saw, in Secunderabad on August 20, 1897, the malarial parasite on the stomach wall of a female *Anopheles* mosquito collected from the mosquito net of a patient with malaria. He later demonstrated that bird malaria was transmitted from sparrow to sparrow by the bite of an infected mosquito; while Bignami, Bastianelli and Grassi in Italy showed subsequently that human malaria was also mosquito-borne. The implications of these findings were immediately clear — mosquito control would automatically control malaria. At that time little was known about the mosquitoes of India. In 1900, Colonel G.M. Giles read a paper before the Bombay Natural History Society, in which he said "Two years ago when I took up the task of collecting the history of the Culicidae…no more than four species were recorded as having been found in all India. There was in fact hardly any known country with such scanty records of the subject."(Covell 1952). Extensive surveys were carried out during the next three decades, which would result in two volumes of the FAUNA OF BRITISH INDIA series on mosquitoes, one on the Anophelini and the other on the Culicini, which have provided a solid basis for much of the great quantity of basic and applied research that has followed. Between 1901 and 1930, ten papers on mosquitoes and malaria were published in the *Journal of the Bombay Natural History Society*, and these are listed by Covell (1952). Today 365 species of mosquitoes have been recorded from India.

Only the genus *Anopheles* can transmit human malaria. There are 59 species on the Indian list today, of which 8 have been incriminated as major vectors (*A. culicifacies, A. stephensi, A. fluviatilis, A. minimus, A. dirus, A. sundaicus, A. annularis* and *A. philippinensis*). Six other species are considered to be secondary vectors in localised areas (Ramachandra Rao 1984).

A. culicifacies is probably the most widespread rural vector, and also plays a role in the outlying suburbs of major cities, such as Delhi. This species breeds in pools and the slow-flowing water at the grassy edges of streams and rivers. It is quick to adapt to man-made breeding sites, and has been the main incidental beneficiary from irrigation projects over the country. Thus it breeds prolifically in pools within irrigation canals and channels when water is not actually flowing in them, in rainwater standing in rocky hollows exposed in dry riverbeds created by dams, in borrow pits and seepages from canals, and to some extent in fields newly planted with rice[1]. However, there was always a puzzling lack of correspondence between the distribution and population density of this species and the prevalence of malaria. In recent years it has been shown that taxa once believed to be a single species are in fact groups of sibling species, which are morphologically identical but which can be separated by cytological techniques. Five sibling species are known in *A. culicifacies* in India, named species A to E. Two or more sibling species may be sympatric, and sterile hybrids are found in nature. All the sibling species are zoophilic, i.e. they prefer to feed on cattle rather than on man, but the relative degree of feeding on man varies considerably. Species B rarely feeds on man, while species A and sometimes C in northern India and species D and E in southern India do so relatively frequently. It is no surprise, therefore, to find that the last four are potent vectors, and many infective individuals have been found in dissections of wild-caught females. B is a poor vector, if at all, and only one wild-caught female, reliably identified as species B, has been found to be positive for the malarial parasite (Suguna *et al.*

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[1] *Anopheles culicifacies* is generally regarded as a rice-field breeder, mainly on the basis of studies in the 1930s in Pattukotai district in Tamil Nadu. However, many recent studies in the same and other parts of Tamil Nadu have shown that the species is not breeding extensively in this habitat.

1983) in several long series of dissections. *Anopheles culicifacies* s.l. is not a vector in forested areas, but is known to replace other vector species in the wake of deforestation in the Western Ghats (Tewari *et al.* 1987). In Orissa, another species, *A. fluviatilis* was found to transmit malaria in forest villages, where *A. culicifacies* species B and C were also present but not feeding on man. In deforested areas where *A. fluviatilis* had been replaced by *A. culicifacies* species A, this was the main vector (Nanda *et al.* 2000). Surveys in 3 topographically different areas in Uttar Pradesh showed a good correlation between sibling species composition in the population of *A. culicifacies* and malaria incidence. Sibling species A, B, and C coexisted here, and where the proportion of the non-vector species B greatly exceeded the other two, malaria endemicity was low. Conversely, in a zone of high malaria transmission, the population of A and C together was about the same as B (Tiwari *et al.* 1994).

A. stephensi is the major vector of malaria in urban areas. This species has adapted to the peri-domestic environment, and breeds freely in domestic wells, water-storage containers, concrete cisterns and overhead tanks. It also breeds in ponds and streams in rural areas of northern and peninsular India, but apparently not in Tamil Nadu, where several long-term studies have confirmed that it is confined to small towns and cities, and is absent from villages even in malarious areas. No sibling species have been described in *A. stephensi*, but the rural form has been separated on the morphological characteristics of the egg as variety *mysorensis*. In the environs of Delhi, a form has been described intermediate between the type and variety *mysorensis*.

A. fluviatilis is a widespread and dangerous vector of foothills and forests. It requires flowing water to breed, and thrives along the grassy verges of forest streams. Three sibling species have been described, named species S, T and U. Here too the blood-feeding habits of the various sibling species determine their capacity to transmit malaria. Thus, in Orissa sibling species S was strongly anthropophilic (man feeding), and in villages where it was dominant it was the major vector (Nanda *et al.* 2000). Species T and U are zoophilic, and in the Bhabar and Terai of Uttar Pradesh where they are sympatric, they are poor vectors, and other vector species transmit malaria (Shukla *et al.* 1998).

A. minimus also breeds in streams and water channels, and is the main vector of the northeastern states. It also transmitted malaria in the Bhabar and Terai, but in the early years of the National Malaria Eradication Programme it disappeared. After the clearing of this belt for agriculture, it has been largely replaced by *A. culicifacies* s.l. and *A. fluviatilis* s.l.

A. dirus is another vector species in which 7 sibling species have been described in south and southeast Asia. Two of them occur in India, sibling species D, which is a major vector in the northeastern zone, and the rare species E in the forests of Wynaad, in southwestern India. These species breed in undisturbed deep forest in pools and in transient rainwater collections like elephant footprints.

A. sundaicus breeds in brackish water, and was once an important vector in coastal areas of Bengal and Orissa, from which it seems to have disappeared. It is, however, an important vector in the Andaman and Nicobar Islands. *A. annularis* transmits malaria in Assam, Bengal and coastal Orissa and *A. philippinensis* in deltaic Bengal, Assam and Meghalaya.

The varied habits of malaria vectors in different parts of the country greatly complicate control efforts.

CONTROL OF MALARIA

Early attempts to control Anophelines

There was at best mixed success for early attempts to reduce the incidence of malaria. Simple methods were used, such as draining and filling anopheline breeding-sites in shallow standing water, and treating others which could not be removed with kerosene. It was soon realized that since mosquitoes could fly from a distance of at least 3/4 of a mile, control efforts must be undertaken simultaneously over large tracts. Generally, anopheline breeding in rural tracts was diffused over vast areas, and frequently it was found that the amount of organisation, supervision, labour and expenditure involved made control impracticable. Some successes were documented, mainly in places in which economic interests were involved, notably at dam sites. In such situations, minor engineering work could remove unnecessary stagnation of water, and canals could be lined with concrete to prevent seepage. Without these measures and the early detection and treatment of malaria cases among labour, it would have been impossible to complete such projects. In the tea gardens of Assam, breeding of the vector *Anopheles minimus* in water channels was prevented by growing shade bushes along them. This prevented the growth of grass along the edges, which proved to be critical for the breeding of this species. Mosquito screening of labour lines also helped to reduce the loss of man-days due to fever.

The great success story of this period was, however, the control of malaria in Bombay (= Mumbai). This city was always considered to be unhealthy, and a blood survey in 1911 showed that 2,542 fever cases among the City Police were caused by malaria. Bentley (1911) found that *A. stephensi* was responsible. Since this vector breeds in easily located and well defined breeding sites, he thought malaria could be controlled here more easily than elsewhere by permanently closing domestic wells and installing pumps, filling up unwanted wells, and making overhead tanks (the other major source of vectors) mosquito proof. Ornamental ponds and fountains were stocked with larvivorous fish. Bentley and his successor Captain Chalam, managed to keep parts of Bombay relatively free from malaria. It was, however, Major Covell (1928) who organised the work and made detailed recommendations including penal provisions of the Municipal Act for those who did not cooperate. He also succeeded in getting sanction for a permanent staff for malaria control, facilitated reportedly because the Governor of the state came back from a hunting trip and fell ill with malaria (Ramachandra Rao 1984). The result was the complete elimination of malaria transmission, with the only cases reported in the city being imported from outside.

However, this example and the partial successes elsewhere remained localised and had little impact on the larger problem of malaria in the country.

The DDT era

The discovery of the residual insecticidal action of DDT made it possible to target the adult anopheline female mosquito, which rests on walls and ceilings after feeding and can pick up a lethal dose of insecticide. Pilot studies were very encouraging, and a National Malaria Control Programme (NMCP) was launched in 1953. This was so successful in reducing malaria incidence that the programme was converted, in 1959, into the National Malaria Eradication Programme (NMEP), rightly described as the single largest public health programme in the world. It received technical support from WHO and donor support from international agencies.

Meanwhile, there were warnings. In 1962, Rachel Carson published her book *Silent Spring*, highlighting the damage caused to the environment by large-scale pesticide use. This led to a complete ban on the use of organochlorines for agriculture, but exempted the use of DDT for public health use. Spraying within houses was considered minimally damaging to the environment, and links with cancer have not been confirmed in several carefully carried out epidemiological studies made since. Besides, in the '60s DDT was saving lives. While there was no adequate surveillance system before 1953, it was estimated that there were 75 million cases of malaria and 800,000 deaths each year in India. Numbers fell rapidly after control, till in 1965 only about 100,000 cases were reported, and no deaths. It is also important to remember that at that time the NMEP was an *eradication* programme, with a definite timeframe, and residual spraying was never intended to continue indefinitely. But after 1965 the setbacks began, and there was a resurgence, which reached a peak of around 6.5 million cases in 1976. Changes in strategy brought numbers down somewhat, but cases have stagnated at between 2 and 3 million annually, with about 1,000 deaths. The programme managers clung to the mindset of the eradication era long after it ceased to be useful. It was only in 1995 that there was a change of name to National Anti-Malaria Programme (NAMP).

The reasons for the resurgence of malaria have been discussed and analysed many times: technical factors such as the development of resistance to insecticides, administrative failures including inadequate planning, shortage of funds and staff, and poor training of personnel. It has to be remembered, however, that in spite of the setbacks, malaria incidence has not returned to the previous level. Nevertheless, there is little cause for complacency, since under-reporting is a serious concern. Though the official figures show that at present numbers of cases are between 2 and 4 per cent of the pre-control level, the correct figures may be between five and fifteen times higher (SEARO 2000). Under-reporting of deaths is still more serious. Scientists of the Malaria Research Centre, Delhi, believe that only 1 in 200 malaria deaths is being reported. Even more disturbing is the increasing proportion of cases caused by the malignant *Plasmodium falciparum.* In 1970 about 14 per cent were caused by this species, but by 1999 the proportion was 50 %.

Changes in land usage have sometimes contributed to the problem. For example, the Thar Desert region was formerly only mildly prone to malaria, transmitted by *Anopheles stephensi* breeding in traditional water storage reservoirs. Following the introduction of canal irrigation and cultivation over wide areas, *A. culicifacies* has established itself. Between 1961 and 1994, total malaria incidence as well as *falciparum* malaria has increased 3.5 times (Tyagi *et al.* 1995).

Urban areas were not sprayed with DDT and other insecticides. In many towns urban malaria schemes, based on the Bombay model and paid for by municipalities, were implemented with varied success. In Bombay itself, control remained exemplary with strict implementation of the Municipal Act and good supervision until comparatively recently. Most of the credit for this belongs to P. B. Deobhankar, Insecticide Officer of the Municipality. After he retired in the early 1990s, the system appears to have broken down and indigenous transmission of malaria is on the rise. Damaged overhead tanks in old buildings and water storage drums in slums provide breeding sites. However, most of the cases occur in association with construction sites. *A. stephensi* is quick to breed in the small cisterns which are built and filled with water used for pouring over fresh concrete structures. These are not emptied for long periods, nor does the builder now fear inspection and prosecution. The source of malaria infection is usually migrant labour at construction sites. A focus of transmission quickly develops, which will shift to another site when building is completed.

Where do we go from here?

At the beginning of the 21st century, we face a deteriorating malaria situation, with high levels of resistance to DDT in vector mosquitoes, and also widespread resistance in humans to chloroquine (the frontline drug for treatment) besides prospects of rapid development of multi-drug resistance to other common drugs. All the same, Dr. Gro Harlem Brundtland, Director General of WHO, plans to halve malaria mortality by 2010, and again halve it by 2015. There is no major breakthrough in technology, but the new strategy stresses flexibility, political commitment and resource mobilisation to deploy existing techniques with improved organisational skill (SEARO 2000).

One of the most hopeful research developments of recent times has been the treatment of bed-nets with synthetic pyrethroids, to protect communities from mosquito bites. Pyrethroids have a chemical structure based on the natural product pyrethrum, and combine the advantages of a more powerful insecticidal action and very low mammalian toxicity. Permethrin, deltamethrin and lambdacyhalothrin are among those which have been used for this purpose. An untreated bed-net gives protection only as long as it remains without holes. A treated net with holes, however, will drive away blood-seeking mosquitoes because pyrethroids have an irritant and repellant effect, and will also kill those which rest on it for long enough to acquire a lethal dose. If the whole community sleeps under insecticide treated nets (ITNs) there will be a significant impact on malaria transmission.

This technology was tested in Assam, where *Anopheles minimus* was a suitable target because biting peaked around midnight, a time when it is possible to protect people with nets. Treated nets were distributed in 3 villages, untreated nets in others and yet others served as controls. They were well accepted by the tribal population. The nets provided a high degree of personal protection from mosquito-bite, while in the villages with ITNs the population of *A. minimus* was also reduced. Malaria incidence was monitored weekly, and rose significantly in the control villages during the study, while remaining at the same level in villages with untreated nets. In villages with ITNs however, there was a significant decline (Jana-Kara *et al.* 1995). In a larger trial covering 126 villages in Gujarat, house spraying with deltamethrin was compared with nets treated with the same insecticide. Here the vector was *A. culicifacies* species A. Again there was significantly lower incidence in ITN villages than in sprayed villages, and both were significantly better than villages without any interventions (Misra *et al.* 1999). These results are very similar to those obtained in other parts of the developing world (Curtis and Mnzava 2000). Thus, ITNs could be of use in an integrated programme of control in both these areas.

But the real test of ITN technology in India is among the adivasis of Orissa, who live in areas where the health infrastructure is weakest, and where malaria control made no impact because residual spraying was never socially acceptable to the people. In parts of Orissa, villagers wait patiently till spraying is over, and then start mud-plastering their walls to cover the unsightly white stains left by DDT. Yet the spraying is carried out regardless each year. Orissa accounted for about 20 % of all malaria cases in India, 38 % of all the *falciparum* and 55 % of all malaria deaths reported in 1991. Two studies have been carried out which have shown striking reduction in populations of the vector, *A. fluviatilis* species S, due to the use of ITNs (Jambulingam *et al.* 1989 and Yadav and Sampath 1993). These were followed by a Social Marketing Project in Keonjhar District run by the Government of Orissa, the British Council, CARE and the Malaria Research Centre. This sought to help communities to generate demand for nets and run their own malaria control projects. Dr. John Oommen, working in the Community Health Department of a small hospital in Rayagada District in Orissa, which provides primary health care to a population of over 10,000 in 46 villages, has taken this approach still further. The Bissam Cuttack Block, where this hospital is situated, is one of six blocks in Orissa which showed a negative rate of growth in the 1991 census, with deaths outnumbering births. Fever was the single largest cause of death, particularly in the under-five age group. Many of these deaths occurred at home and no blood smears were obtained, but it is very likely that they were due to malaria. Dr. Oommen works to set up a people's movement against malaria. Through 1996 and early 1997, 38 villages opted for malaria education and for ITNs, which they paid for by instalments, convinced that the economic losses due to malaria outweighed the cost of the nets. Hospital records showed that in 1997 fever cases had dropped by 36%, fever deaths by 40% and hospital admissions for malaria by 39% by comparison with the previous year (Oommen *et al.* 1999). Overall child mortality due to any cause also fell to about half (Dr. J. Oommen, pers. comm.). The reason for this is that malnourished children with malaria have a lowered resistance to other infections as well[2]. Much larger trials involving NGOs, research organisations and the District administration, are now underway in Malkangiri and Gajapati districts in Orissa.

Clearly, nets have an important role to play in an integrated vector control programme, but they will not be suitable in situations where malaria transmission takes place mainly outdoors, or early in the night. Can the technology be made cost effective? DDT is still the cheapest insecticide but is no longer effective in reducing malaria to acceptable levels. Malathion is 3 to 4 times more costly, though more effective in controlling vectors, but coverage declines due to refusals because of its unpleasant smell. Synthetic pyrethroids are very effective but somewhat more costly than malathion. If ITN technology can be made effective the cost will be less than that of DDT spraying (SEARO 2000), because less insecticide is required per household to treat nets. Optimal results depend on the mass effect on vector populations rather than personal protection of those sleeping under nets. While people are often willing to pay the initial cost for ITNs, they are reluctant to pay the additional cost of annual re-treatment. Curtis and Maxwell (2002) believe that the full potential of the method can best be achieved if insecticide treatment is provided free, citing the example of Vietnam, where 11 million people are now protected by treated nets, and insecticide is provided free as a public health service. A major decline in malaria incidence has resulted [Tran Duc Hinh 2001 (www.Mekong-malaria.org/meis/mmf6/mmf6 15htm) in Curtis and Maxwell 2002]: one of the few successes of malaria control on a national scale in recent times.

Since there is a strong likelihood that resistance to pyrethroids may develop as a result of widespread use of treated nets, non-pyrethroid alternatives with low toxicity, for example carbosulphan, are already being tested for treating nets. Early results suggest that non-irritant insecticides, which do not repel mosquitoes, may kill more efficiently than pyrethroids and therefore result in much better control of malaria than before (Curtis, in press). Encouraging as these developments are, ITNs should be only one component in an integrated programme.

Does indoor residual spraying still have a role? Today, there appears to be little justification for the continued use of DDT in India. But there are some African countries and parts of Latin America with a heavy burden of malaria, in which it can still save lives. Considerations like these led to the resolution of the International Convention on Persistent Organic Pollutants in December 2000, which allowed the continued use of DDT for vector control in 28 countries, provided that WHO guidelines were strictly followed. These countries are also expected to develop alternatives, and their progress towards this objective is to be reviewed after 3 years.

In India, bio-environmental control, including source reduction, is still the method of choice wherever anopheline breeding sites are well defined and accessible, as they are in urban areas. Larvivorous fish such as *Gambusia*, *Tilapia* and some of the carps, have proved their worth in wells, pits and ornamental tanks, and an added advantage is that edible fish can be sustainably harvested to add to family or community income. *Bacillus thuringiensis* var. *israelensis* has not been extensively used in India. While it kills anopheline larvae effectively, it does not cycle in nature, and therefore recurrent re-treatment of breeding sites is necessary. Still a long way in the future is the possible replacement of natural populations of vectors by transgenic mosquitoes into which a gene for refractoriness to malaria has been inserted. Such a gene has been found, and modified mosquitoes feeding on malaria-infected mouse blood are 80% less likely to have malaria in their salivary glands, and they are almost totally unable to pass on malaria to other mice (Ito *et al.* 2002). However the resistance gene for human malaria may not be the same, and in any case great caution would have to be exercised before genetically modified mosquitoes could be released into the environment.

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[2] Reduction in overall childhood mortality as a result of community use of ITNs has been well documented in several studies in Africa.

In conclusion, there is one important lesson of the India experience that needs to be emphasized — that vector control which is also environment friendly is practicable. But in addition to research, good management is a prerequisite for major success. Covell and Deobhankar were outstanding managers within the government system, while the potential of the NGO sector is now being demonstrated by Oommen and others. There is real hope that these successes can be replicated, and that malaria can be effectively controlled without the release of toxic chemicals into the environment.

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ZOOLOGICAL SURVEY OF INDIA AND ITS IMPACT ON THE STUDY OF FIELD ZOOLOGY IN INDIA

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Key words: Zoological Survey of India, field studies, marine surveys, expeditions

The Zoological Survey of India came into existence in 1916. In the first half of the 20th century, that is, in British India, its surveys and expeditions were not limited to the Indian subcontinent, but extended as far as Iran, Ethiopia, Palestine, Tibet, Thailand, China and Japan.

In the marine field, as an offshoot of the earlier Marine Survey of India, the *R.I.M.S.S. Investigator* carried out deep-sea trawling in Indian territorial waters.

There was a lull, forced by financial constraints, between 1931 and 1946. After India's independence in 1947, surveys and collections were limited to India, but were carried out on a more extensive scale. Exceptions were the brief forays, where the Survey's scientists joined forces with other international institutions, such as the U.K. *Daily Mail* Himalayan Expedition in 1954, Cho Oyu Expedition to Nepal (1958), Harvard Yale Expedition to Sikkim in 1958 (Sikkim was then not part of India), Indo-German Expedition (1955-58), Indo-Swiss Expedition, Ross Expedition (1961-62) and Royal Ontario Museum Expedition.

In the sea, ZSI scientists participated in the International Indian Ocean Expedition from 1962-64, with the Defence Research and Development Organisation and on board *I.N.S. Darshak* (1973-74).

With the creation of several regional and field stations in the third Five Year Plan (1961-66) and a field station at Kakdweep in 1979, specialised ecological studies can now be carried out for desert, alpine, grassland, forest, marine and coral reef habitats. With current emphasis on the environment and wildlife conservation, ZSI has now also branched out into these fields, apart from biodiversity conservation and bioprospecting, environmental impact assay, animals in relation to tribals and joint collaboration for agriculture, forestry, fisheries and public health.

INTRODUCTION

The importance of field studies in any exploratory and bio-ecological research needs no mention. In order to understand the occurrence, abundance and distribution of species in space and time, its interrelationship with the biotic and abiotic factors of the environment and its mode of life, particularly feeding and reproduction, extensive and intensive field studies are essential prerequisites. Today, the Zoological Survey of India is the only organisation in the country with a massive set-up for survey and exploration of faunal diversity in different eco-zones in all parts of the country. It has its field establishments right from the high altitudes of the Himalaya to the Indian Ocean, from the deserts of Rajasthan to the tropical rainforests of the Northeast. There is hardly any ecosystem in the country, where the scientists of the Zoological Survey of India have not carried out their field studies. This is clearly evident from the huge National Zoological Collection maintained at Headquarters and in the sixteen Regional Stations located throughout the country.

HISTORICAL RÉSUMÉ OF FIELD STUDIES

Pre-independence

The Zoological Survey of India (ZSI) was established in 1916 as an offshoot of the Indian Museum, Zoology Section, primarily to promote survey, exploration and research leading to the advancement of our knowledge of various aspects of the exceptionally rich animal life of the erstwhile British Indian Empire. Initially, the ZSI acquired more than a century old zoological collections from the former Museum of the Asiatic Society of Bengal and the Zoology Section of the Indian

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Museum. The main task of the Indian Museum (1875-1916) and the Asiatic Society of Bengal (1814-1875) was to identify and exhibit the zoological collections deposited by explorers and naturalists of British India when organised field studies for fauna were very limited. However, it was soon realised that the job of the Survey was not purely museum taxonomy, and without detailed field studies, any conclusion regarding the habit and habitat of a species would not be very meaningful.

Going back to the contribution of early zoological explorers, the foremost name is that of Dr. John Anderson who made two expeditions into Yunnan (China) in 1868 and 1875. Thereafter, various other collections came from regions as far apart as Ethiopia, Iran, Tibet, and from different parts of India and Burma. Even today, the Survey holds the collections and field notes made by naturalists during the Persian Boundary Commission (1870-72), the Second Yarkand Mission (1873-74) and the Dafla Expedition (1874-75).

The next phase of field studies was undertaken when the British Government formed the Marine Survey of India for investigation of deep-sea fauna. This task was assigned to the Surgeon Naturalist attached to the Marine Survey of India. The deep-sea explorations started in 1822 when the *Royal Indian Marine Survey Ship Investigator* was launched. It was under the able and dynamic leadership of distinguished scientists like Lt Col. Alfred William Alcock, the Surgeon Naturalist, who conducted extensive and intensive deep-sea field studies. The material brought back by the *Investigator* provided, for the first time, a foundation for the systematic study of the deep sea and its inhabitants.

A number of expeditions and field zoological studies were made in various parts of India and even beyond its frontiers. Mention may be made of the expeditions by T.N. Annandale to the Lake of Galilee, Tiberias, Palestine; to the Tale Sap in Thailand; and to Lake Biwa in Japan. During this period, extensive field studies were carried out and valuable collections of both land and freshwater fauna were made during several political and military expeditions.

Exploratory field studies gained considerable importance after the official creation of the Zoological Survey of India, as an independent organisation. The post of Surgeon Naturalist, Marine Survey of India, was transferred to the ZSI in 1920. Major R.B. Seymour Sewell, a Surgeon Naturalist, also became a member of the Survey with a rank of Superintendent. Fieldwork was then considered one of the most important duties of the Survey and thus detailed programmes of work were formulated which were carried out over the years under the leadership of Dr. Annandale, including a pioneering field survey of Chilka Lake.

It was a landmark in the field studies of the Zoological Survey of India, when the ruling British Government expressed its concern regarding the spread of Schistosomiasis, and asked the Survey to undertake detailed studies on freshwater molluscs with a view to investigate the possibility of their acting as vectors of human Schistosomiasis. The other important field studies during the period were on the fauna of Siju Cave.

The seeds of environmental research were already being sown at the Zoological Survey of India, even during those early years. Two areas that were undergoing considerable change as a result of certain engineering schemes were investigated. The first of these was Manchar Lake in Sind (now in Pakistan) after the erection of the Sukkur barrage on River Indus, and the second was Vishakapatnam, where changes were likely to occur as a result of the construction of a harbour in this area.

The period between 1931 and 1946 was difficult for the ZSI because of a massive financial crunch; long distance surveys and field studies suffered greatly. However, even during this lean period, extensive ecological and taxonomic surveys were carried out in the vast wetland areas of the erstwhile north and south Salt lakes of the Sunderbans. Regular field trips were made and extensive studies were carried out on the fauna in that wilderness.

Post independence

The early post-independence period was marked by the notable contribution of the Survey under the dynamic leadership of Dr. Sunder Lal Hora. During this period, important field studies were conducted on the aquatic and terrestrial fauna of the areas which were to be affected by the proposed Rihund Dam and Damodar Valley Projects. As a result, special surveys of the dam sites were initiated, to find a solution to the problems regarding fish passes and fish ladders, in collaboration with the Central Board of Irrigation and Power.

During the first Five Year Plan, the services of the Survey were utilised by numerous institutions and workers interested in the application of zoological knowledge to practical problems. Preliminary assessment of the wildlife resources of the country was also carried out. Field studies were conducted in (i) Pachmarhi (Madhya Pradesh) in search of relict elements of the last glacial period, (ii) south Malabar for Malayan elements of fauna; (iii) Sikkim in collaboration with the Bombay Natural History Society (BNHS) on the migration of high altitude birds, and (iv) Darjeeling for studies on a rare egg-eating snake. During this period, the Survey also participated in the London based newspaper, the *Daily Mail*'s Himalayan Expedition (1954) to Nepal in search of the Abominable Snowman, popularly called Yeti [which as is now known is the Himalayan brown bear — Eds].

During the second Five Year Plan (1956-57 to 1960-61), extensive field studies were carried out in the desert of Rajasthan and former French pockets in south India. Comprehensive surveys of the Andaman and Nicobar Islands and Gir forest were undertaken. Ecological studies on the shipworms of Sunderban were also carried out. Besides these, the Survey also participated in the Indian Cho Oyu Expedition (1958) to Nepal, the Harvard Yale Expedition (1958) to Sikkim and Darjeeling for birds, the Indo-German Expedition (1955-58) to different parts of the country for assessing the vertebrates, and the Indo-Swiss Entomological Expedition to northwest and northeast Himalaya. Special field studies on the population dynamics of desert locusts in India and termite fauna of the country were also carried out.

The third Five Year Plan (1961-66) saw a glorious period in the history of the Zoological Survey of India when major expansion in the organisation and fieldwork were done. Several new regional/field stations were created in order to cover various ecosystems of India. During this period, extensive studies were carried out at the construction site of the Nagarjunasagar Dam to record the ecological faunal succession on the completion of the dam. Besides this, several other important surveys were undertaken, which included: (i) Coastal Survey of Orissa, Andhra Pradesh, erstwhile Madras and the Gulf of Mannar for marine organisms, (ii) the Andaman and Nicobar Islands, (iii) the Western Ghats, and (iv) Rajasthan and Goa. Several scientists of the Survey also participated in Mahanadi estuary field studies, with particular reference to shipworms. Besides these, our scientists participated in the faunistic survey programmes of the International Indian Ocean Expedition (1962-64) on board *I.N.S. Kistna* and the Russian ship *Vityaz*. Other important studies conducted during the period include census of the spotted deer or chital (*Axis axis*) in Dehra Dun forest, Joint Exploration to Andaman sea, Andaman and Nicobar Islands and NEFA with the Defence Research and Development Organisation (DRDO). The Survey also participated in the Ross Expedition (1961-62) to different regions of India for the study of insects, and the Royal Ontario Museum Expedition to Anamalai Hills in Tamil Nadu for general faunistic collection.

During subsequent annual plans and the fourth Five Year Plan (1966-1974), the most noteworthy field surveys undertaken were to Bhutan for birds, Burzahom (Jammu and Kashmir) for animal remains of prehistoric times, Kerala coastal areas for wood borers, and the Andaman and Nicobar Islands for marine organisms. The scientists of the Survey also participated in Multidisciplinary Scientific Expeditions to Daphabum (1969-70) and Subansiri (1974-75) in Arunachal Pradesh, and the Rupkund and Tons Valley Expedition to Uttar Pradesh. Special emphasis was also given to the survey of national parks and sanctuaries, particularly Corbett National Park in Uttar Pradesh, Kanha National Park in Madhya Pradesh, Hazaribagh National Park in Bihar, and Kaziranga Wildlife Sanctuary in Assam. Further, the Garo Hills in Meghalaya, Narmada river valley in Madhya Pradesh, Western Ghats in Karnataka and Kodaikanal, and Palni Hills in Tamil Nadu were also surveyed for general wildlife fauna. The Peacock survey was taken up with National Sample Survey Organisation. A joint oceanic expedition on board *I.N.S. Darshak* of the Naval Hydrographic Department the Arabian sea during 1973-74 was conducted and data was collected on the sonic scattering layers, along with samples of zooplankton, nekton and benthos.

Scientists participated in the oceanic expedition with *R.V. Chota Investigator* for pollution studies at Madras (=Chennai); the BNHS and WWF Expedition to Ladakh (1976) for the status survey of the black-necked crane, bar-headed goose and several wild goats and sheep. ZSI personnel also participated in the Indo-Japanese Entomological Expedition (1978-79) to northwestern and southern India, and the multidisciplinary, inter-institutional expedition to Sikkim (1978-79).

Projects such as the impact assessment of bio-ecological changes in the faunal patterns brought about by partial submergence of Corbett National Park, eco-ethological studies and population estimates of the Cercopithecid primates of peninsular India, status survey of endangered and threatened species of animals and birds of Nanda Devi Sanctuary, population of rhesus macaque and hanuman langur of India, effect of pollution on some organisms in zooplankton, benthos and nekton contributing to the food chain in marine environment, etc. emphasising field zoology were undertaken.

Thereafter, new lines of research on ecology were undertaken, namely: nematode pests of crops and their control, bio-ecological studies on soil microarthropods, the biology, ecology and distribution of a land snail; ecological interaction of the Xylophagous insects of the Andaman and Nicobar Islands, population periodicity and ecology of the vector of Kala-azar in north Bihar; abundance and seasonal fluctuation of Phlebotomid sandflies in north Bihar. Other studies undertaken were: filth inhabiting flies of Calcutta (=Kolkata); prevention of fouling organisms in the cooling sea water system of the thermal plant at Tuticorin; Meiofauna of Sagar Islands; biological rhythms of the Indian false vampire *Megaderma lyra*; study of light-attracted insects; bioecological studies on *Macrosiphoniella sanborni*, a pest on Chrysanthemum; species composition, population fluctuations and ecological succession of thrips; population ecology of the most endangered species of mammals and birds in the arid zones of Rajasthan and Gujarat; parasitic Hymenoptera and other predatory insect resources of the northeast Himalaya; ecological and environmental impact of multipurpose river-valley projects, with particular reference to the Idukki Hydroelectric Project.

Impact of Field Zoology

Contributions from the field explorations conducted by various scientists resulted in special publications such as INDEX HORANA; SIPHONOPHORA FROM INDIAN OCEAN as well as ECTOPARASITES OF BATS OF RAJASTHAN. Other field zoology publications include: Odonate distribution in western Himalaya, Taxonomic studies of earthworms collected during Subansiri Expediton of Arunachal Pradesh, Spider fauna of Calcutta and its vicinity with special reference to the revision of Indian crab-spiders. The ZSI also published Catalogues of oriental Dermaptera, Crustacea; Memoirs on Freshwater Sponges and Polyzoa; Catalogues of Stomatopoda, Passelid beetles. Publications on Francis Day and his collections of Indian fishes; Aphids of economic importance; Termite pests of agriculture, Taxonomic studies of some of the Indian non-mulberry silk moths; Taxonomy, ecology and biology of nematode associated with jute crops; Taxonomy of Chaetognatha; and a monograph of the tongue soles of the genus *Cyanoglossus* Hamilton were also brought out by the Survey. Special volumes on conservation issues include: Habitat suitability analysis of the Chinkara *Gazella bennettii* in Rajasthan — a remote sensing approach; Effects of heavy metal contaminated sewage effluents on the soil arthropods in and around Calcutta; Water Birds of North India; Fig insects of Kerala; Ecology of soil orbtid mites; Habits and habitats of Dragonflies of Northern India; etc. Several 'Wetland' and 'Fauna of India' series were other important contributions based on field studies.

However, the priorities of the Survey were defined in 1987, when the Ministry of Environment and Forests allotted a targeted programme for the following decade. The ZSI was asked to reorient its priorities under: (i) Fauna of States, (ii) Fauna of Conservation Areas, (iii) Fauna of Important Ecosystems, (iv) Status survey of endangered species, and (v) Ecological/Behavioral studies. In brief, the areas for study envisaged then were:

1. Himalayan Ecosystem (Western, Central and Eastern)
2. Desert Ecosystem (Gujarat, Rajasthan and Ladakh)
3. Tropical Rainforest Ecosysem
4. Marine Island Ecosystem
5. Fauna of States
6. Selected Estuarine and Brackish and Freshwater Ecosystems
7. Biosphere Reserves, Mangroves and Protected Areas

The Survey has carried out extensive surveys in the areas mentioned above. However, it was realised that the time frame allotted for such vast field studies was not sufficient and, therefore, the targets were revised so that greater emphasis could be given to field studies, particularly in the post-biodiversity convention scenario.

Current field programmes

Currently the Zoological Survey of India with its huge organisational setup consisting of its Headquarters at Kolkata and 16 regional/fields stations located in different parts of the country — Dehra Dun, Shillong, Jodhpur, Jabalpur, Chennai, Solan, Patna, Pune, Port Blair, Itanagar, Kozhikode, Hyderabad, Berhampur, and Canning and Digha in West Bengal —carry out regular surveys in the respective areas in order to achieve the assigned targets. Besides, the specialist scientists at headquarters carry out fieldwork related to their specialisation. Some of the recent field programmes of the Survey include: (i) Coral reef and coral associates in the Andaman and Nicobar Islands, Gulf of Mannar in Tamil Nadu, Gulf of Kutch in Gujarat and Lakshadweep, (ii) Habitat suitability and analysis based on the GIS, (iii) Re-survey of Chilka lagoon, (iv) Primate studies in northeast and southern India, (vi) Desert, marine, freshwater, mountain ecosystem studies (vii) Tropical Rainforest ecosystem studies, (viii) Status survey of Endangered species (ix) Studies on selected Protected Areas, and (x) Ecological studies on insects and mites of economic importance.

Field studies in relation to public service

A large number of field studies carried out by the scientists of the Zoological Survey of India have a direct bearing on various aspects of public life, some of which are:

Biodiversity conservation: The faunistic exploratory studies conducted provide baseline data on the rich faunal diversity of the country, which is the basis for conservation of these bioresources.

Agriculture: Studies on economic values such as damage to agricultural crops by rats (with special reference to *Bandicota* sp. and *Rattus* sp.); bats and birds in eastern and northern India; damage to vegetable crops by mites; nematodes associated with paddy and citrus crops; orthopteran and hemipteran pests of crops and vegetables; stem borers and other harmful species.

Forestry: Studies on the ecological interaction of xylophagous insects (timber pests) of Andaman and Nicobar Islands, woodborers and defoliators of forests in West Bengal, damage by termite fauna in general.

Fisheries: The studies on the production ecology of ponds, reservoirs and lakes, biology of commercially important freshwater and marine fishes, studies on edible crabs, commercially important freshwater and marine fishes of India, all these leading to the improved fish catch and harvesting.

Public health: Studies on the biology and ecology of mosquitoes and sand flies in eastern and southern India, helminth parasites and their vectors, and haematozoan protozoa, in the interest of human health.

Environmental conservation: Causes and remedies of the water pollution of some lakes (urban lakes of Hyderabad and Kolkata), reservoirs, rivers (Ganga, Damodar, Hoogly-Matla) and coastal waters (Chennai coast), industrial soil pollution in Durgapur region and its monitoring by soil microarthropods, as a part of conservation studies.

Wildlife conservation: Ecological and behavioral studies on some avian species of northern India; Tibetan wild ass; wild ass of Rajasthan and Gujarat; macaques, langurs and hoolock gibbon, antelopes and deer of Rajasthan and Madhya Pradesh; lesser cats and giant squirrels of north Bengal; elephants of wildlife sanctuaries of Orissa, Bengal and Bihar; and status survey of some important endangered species, where many of them are keystone species or umbrella species.

Animals in relation to tribals: Detailed studies on the relationship between various tribals and animals in northern, eastern and central India and the Andaman and Nicobar Islands, pertaining to the utility of animals for food, medicine, fertiliser, fuel, dyes, pets, witchcraft, astrology, vectors, totems, taboos, myths, folklore and omens, besides the use of various animal products as ornaments and for decoration.

Specific role of the field studies by ZSI in biodiversity conservation and bioprospecting

The field studies carried out by ZSI are not only important for biodiversity conservation but they also provide valuable information for biotechnology and bioprospecting. Call it bioprospecting, chemical prospecting or gene hunting — a search for wild plant and animal products of potential value to medicine, agriculture, cosmetics and other uses has been going on for hundreds of years. Today bioprospectors gather and study the extracts of everything from spider venom to soil microbes to algae. However, biotechnology and bioprospecting should not be furthered at the cost of genetic and environmental diversity of animals. It is the prime duty of the ZSI to see that technological advances in the biological system do not hamper the natural distribution and abundance of animal species, and at the same time to document all animal species, which at some future time may be useful to mankind. This can only be achieved by collecting information on every species from the single celled protozoans to the largest mammals, the elephant on land and the blue whale in the ocean.

GLIMPSES OF THE PHYTOGEOGRAPHY OF MAHARASHTRA[1]

M.R. Almeida, Suchandra Dutta and S.M. Almeida[2]

Key words: Phytogeography, Maharashtra, endemic plants, exotic plants, continental, endemism

The present paper deals with freshly gathered information on the geographical origin of 5,040 flowering plant species and intraspecific taxa belonging to about 1,600 genera and 215 families found in Maharashtra. Continent-wise analysis has been incorporated. A quantitative report of endemic and continent-wise exotic taxa, monogeneric families and monotypic genera in Maharashtra is provided. Taxonomic identities with reference to phytogeography of some taxa from Maharashtra are analysed. 2 new genera and 4 new combinations are proposed in the text.

Introduction

Phytogeography is a neglected subject in recent years. With the decline in the number of students opting for taxonomy, the significance of phytogeography is also reduced. Except in a few cases of trees like gulmohur, a tree from Madagascar, or *Castanospermum* A. Cunn., a native of Australia, or *Lantana camara* Linn. , a native weed of American origin, we do not have much information on the geographic origin of species. In this paper we have attempted to find out the geographical origin of 5,000 and odd species recorded in Maharashtra, since the first publication of a Catalogue of plants in Bombay Presidency by John Graham, the Presidency Postmaster of Bombay, in 1839.

Present Data on Phytogeography of Maharashtra

There are about 5,040 flowering plant species and intraspecific taxa, belonging to about 1,600 genera and 215 families, found in Maharashtra. There are about 319 species endemic to Maharashtra for which there are no records beyond the State. In addition to these endemics, there are 59 species, which were described originally from Maharashtra and were thought to be endemic but have been subsequently reported from nearby states and are widely distributed. Original manuscript lists along with their native countries and with the synonymy of species and intraspecific taxa are available at the Blatter Herbarium, Mumbai. We have carefully scrutinised records listed for Maharashtra State and eliminated some erroneous plant records. For example, some plants listed by Cooke (1901-1908) from Sindh and Afghanistan of the former Bombay Presidency have been listed as occurring in Maharashtra by Naithani (1990) in his book FLOWERING PLANTS OF INDIA, NEPAL AND BHUTAN, listed after the FLORA OF BRITISH INDIA. Naithani lists the following species from Maharashtra which have been excluded from the present total of taxa:

1. *Maytenus gibsonii* (Kurz.) Naithani & Biswas, p. 94, 1990. (This is a species from Burma named after Alexander Gibson. It is not found in Maharashtra.)
2. *Xanthophyllum bombayanum* Chodat. (Naithani, p. 52, 1990. This species is from Sindh, now in Pakistan).
3. *Ventilago gamblei* Suseng in Engl. & Prantl. (Naithani, p. 97, 1990; Banerjee & Mukherjee, Ind. Forest. 96: 209, 1970).
4. *Smythea velutina* var. *kingiana* Banerjee & Mukherjee (Bull. Bot. Surv. Ind. 10: 251, 1969; Singh & Divekar, J. Econ. Tax. Bot. 5: 281, 1984).

We have been able to ascertain continental nativity for 4,728 species and infraspecific taxa.

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[1] This paper is abstracted from the forthcoming book "Phytogeography of Maharashtra" by the authors. Concept and text of the paper is by M.R. Almeida (senior author); reference work, data generation and statistics are by S. Dutta and S.M. Almeida.

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About 300 taxa remain to be fully ascertained. Continentwise figures of this analysis are given in Appendix I.

We have tried to analyse some important figures about the families, genera and species in Maharashtra which are presented in matrix form in Appendix II.

FAMILYWISE PHYTOGEOGRAPHICAL ANALYSIS OF GENERA AND SPECIES IN MAHARASHTRA WITH THEIR TAXONOMIC SIGNIFICANCE

Capparidaceae A. Juss.

In this family, all the 17 species belonging to 4 genera found in Maharashtra are predominantly Asian in origin. Only 2 species extend beyond Asia, one to Africa [*Capparis decidua* (Forsk.) Edgew.] and the other to Europe (*Capparis spinosa* Linn.). Existence of *C. spinosa* Linn. in wild state in Maharashtra is very doubtful. We observed that the specimens deposited in our herbaria from Maharashtra identified as *Capparis spinosa* Linn., actually belong to *C. murrayana* Graham, an endemic species of Maharashtra, whose distribution in other states is yet unknown. In Maharashtra also, it is known only from two districts — Pune and Raigad. In a recent book, THE DAPURI DRAWINGS by Dr. Henry Noltie (2002; p. 92, Plate 5) there is an excellent drawing reproduced from Dr. Alexander Gibson's collection of paintings deposited at the Royal Botanic Gardens, Edinburgh. It appears that no type material of this species described by John Graham is at present available in any of the herbaria. We herein designate the specimen collected by Almeida from Varandha Ghat on the way from Pune to Mahad (SMA/ R 1149, BLAT) as a "Neotype" of this species.

The other two endemic taxa of Capparidaceae in Maharashtra are *Cadaba linearifolia* (Grah.) Almeida and *Cadaba rotundifolia* var. *longifolia* Almeida. The former has very restricted distribution in Khandesh. It is a bushy shrub with more or less linear or linear-lanceolate leaves. It has been seen only in flower so far. A good description of its fruit is lacking. Some authors merge *Cadaba heterotricha* Stocks with Graham's plant. We have yet not seen an authentic specimen of that species. Another taxon, which was described by Hooker and Thomson (1855) from Mahabaleshwar as a new species, *Capparis longifolia* Hook. f., is wrongly equated by later authors with *Capparis rotundifolia* Rottl., but they differ in many characters. Firstly, the former has very long needle-shaped spines due to which Hooker and Thomson (1855) named it *Capparis longispina* Hk. f. & Thoms. Another distinct character in which it differs from the typical *C. rotundifolia* Rottl. is that it does not have rotund or rounded leaves but more or less ovate leaves with spinous pointed apex. It is a northern replacement of the southern *C. rotundifolia* Rottl. and we have treated it as a variety of that species. Perhaps it could be higher in its rank and may require subspecies status.

Brassicaceae Burnett

Brassicaceae is a predominantly European family with as many as 26 species (17 European) belonging to 15 genera in Maharashtra. 11 species are Afro-Asian with only one (*Sisymbrium irio* Linn.) extending to Australia.

Flacourtiaceae DC.

The family consisting of 5 genera and 12 species is predominantly Asian (Indo-Malayan) in origin, with a few species of genus *Casearia* Jacq. extending to Africa, tropical Australia and America. Earlier this genus was kept under a separate family, Samydaceae, by Bentham and Hooker (1862-1893). However, there is more or less agreement to merge it with Flacourtiaceae. Three species (*Casearia graveolens* Dalz., *C. rubescens* Dalz. and *Flacourtia montana* Graham) are endemic to Maharashtra.

Ancistrocladaceae Wall.

This is a monogeneric family with the type species described from Maharashtra. It is distributed in the southern part of India — from

Mumbai southwards. Another *Ancistrocladus* species reported by Kothari and Moorthy (1993) of the Botanical Survey of India is only a paper record (i.e. a plant record known only from published literature, of which no distinguishable specimen exists). A sterile plant of *A. heyneanus* Wall. which varies considerably in dimension has been named *A. attenuata* Dyer (a Burmese species). At least plants from Maharashtra definitely belong to *A. heyneanus* Wall. Identity and status of *A. attenuata* Dyer remains to be verified.

Malvaceae A. Juss.

Predominantly an Asian family, with 74 species belonging to 17 genera found within limits of Maharashtra. The following non-Asian exceptions are recorded in Maharashtra:

Abutilon crispum (L.) Medic.	Mexico, America
A. pictum Wall.	Brazil, S. America
A. theophrastii Medic.	Europe
Althaea ludwigii Linn.	Afro-Australian
Gossypium barbadens Linn.	Afro-American
Hibiscus schizopetalus (Mart.) Hk. f.	Africa
H. tiliaceus Linn.	Austro-American.

Abutilon ranadei Woodrow is a species endemic to Maharashtra. Very recently it has been discovered outside its type locality.

Bombacaceae Kunth.

This family is known to be represented in Maharashtra by 7 species belonging to 5 genera. The genus *Bombax* Linn. is Indo-Malaysian, while the rest were introduced from Tropical Africa and America. All the 7 species are bird pollinated plants. Species of *Bombax* Linn. are being studied carefully at Blatter Herbarium. Among red flowered plants of *Bombax ceiba* Linn., occasionally white and yellow flowered plants are noted, either solitary or a few individuals together. These isolated occurrences among larger populations of the red flowered community makes them doubtfully distinct on taxonomic ranks and taxonomists like Rev. Fr. Santapau (1967) retained them without any special taxonomic status. More detailed studies are required to settle these discrepancies.

Balsaminaceae A. Juss.

This family consists of 26 taxa belonging to a single genus. 24 taxa are of Indian origin and only 2 are of Indo-Malayan and Sino-Indian distribution. The following taxa have been described from type specimens from Maharashtra:

Impatiens balsamina Linn. var. *corymbosa* Sant.
I. dalzellii Hk. f. — This is the only yellow flowered balsam found in Maharashtra.
I. inconspicua Benth. var. *ramosissima* Cooke (*I. ramosissima* Dalz.)
I. lawii Hk. f. & Thoms.
I. pulcherrima Dalz.

The two species that are exotic and found in cultivation in gardens are *I. balsamina* Linn. and *I. sultanae* Hk. f. The remaining 24 taxa are found in the wild. *I. acaulis* Hk. f. and *I. scapiflora* Heyne occur on wet rock ledges, among trickling monsoon streams and on sides of waterfalls during wet months.

Dispersal of seeds in *Impatiens* spp. takes place by rupturing of capsules with an explosive burst and seeds are thrown very far from the mother plant. It would be worthwhile to study the effect of wetting the seeds and to see what makes them attach to the rock surfaces where the plants are found.

Fabaceae Lindley (Subfamily Faboidae)

There are 364 spp. belonging to 83 genera in Maharashtra. More than 300 species are Asian (Indo-Malayan) and about 62 species come from other continents (25 from America, 14 from Europe, 12 from Australia and 11 from Africa). The following are endemic to Maharashtra:

Alysicarpus belgaumensis Wt.
A. belgaumensis var. *racemosa* (Bth.) Baker
A. glumescens var. *thothatrii* Almeida

A. luteovexillatus Naik & Pokle
A. monilifer (L.) DC. var. *cudaphhensis* Almeida & Almeida
A. narimanii Almeida & Almeida
A. pubescens Laws. ex Wt.
A. salimalii Almeida & Almeida
A. tetragonolobus var. *pashanensis* Almeida & Almeida
A. vasavadae Hemadri
Canavalia stocksii Dalz.
Clitoria annua Graham
C. annua var. *sekharii* Almeida & Chaturvedi
Crotalaria dubia Graham ex Benth.
C. filipes var. *panthakii* Almeida & Almeida
C. lutescens Dalz.
C. orixensis var. *waghii* Almeida & Almeida
C. stocksii Benth.
C. triquetra Dalz.
C. yasminii Almeida & Almeida
Dalbergia acaciaefolia Dalz.
Desmodium alysicarpoides Meus.
D. ritchiei Sanjappa
Erythrina variegata var. *alba* (Blat. & McCann) Almeida
Flemingia tuberosa Dalz.
Galactea tenuiflora var. *minor* Baker
Indigofera dalzellii Cooke
I. deccanensis Sanjappa
I. trifoliata var. *duthiei* Sanjappa
I. trita var. *purandharensis* Sanjappa
I. santapaui Sanjappa
Lepidocoma gracilis Wt.
L. rollae (Billore & Hemadri) Almeida
Nogra dalzellii (Baker) Merr.
Ophrestia pentaphylla (Dalz.) Verdc.
Rhynchosia mollissima Dalz.
Smithia gracilis Benth.
S. bigemina Dalz.
S. oligantha Blatter
S. setulosa Dalz.
Tephrosia sara-almeidii Almeida
T. strigosa (Dalz.) Sant. & Maheshwari
Vigna dalzelliana (O.K.) Verdc.
V. grahamiana (W. & A.) Verdc.
V. khandalensis (Sant.) Raghavan
V. triloba var. *pusilla* Naik & Pokle
V. vexillata var. *sepiaria* (Dalz.) Benth.
V. vexillata var. *stocksii* (Benth.) Baker

Naik (1998) who has worked exhaustively on the flora of Marathwada, has a great understanding of the legumes of Maharashtra, particularly in the Marathwada region, and feels that there is much scope for detailed studies on many of them (pers. comm.). The following genera are common in Maharashtra and some of them are rich in species diversity:

Alysicarpus Desv.
Cajanus DC.
Crotalaria Linn.
Dalbergia Linn.f.
Derris Lour.
Desmodium Desv.
Flemingia Roxb. ex Aiton & Aiton
Indigofera Linn.
Lepidocoma Jungh.
Rhynchosia Lour.
Sesbania Scopoli
Smithia Aiton
Tephrosia Pers.
Vigna Savi

The following genera are not so common in Maharashtra. Many of them are represented by only a few species, while some are very scarce in the number of individuals located:

Alhagi Gagnepin (Asia: Syria)
Clavulium Desv. (Tropical Asia)
Cyamopsis DC. (Asia — only in cultivation in Maharashtra)
Dumasia DC. (Asia)
Dunbaria Wight & Arn. (Asia)
Eleiotis DC. (Asia)
Galactea P. Browne (Asia)
Glycine Willd. (Asia: China)
Ophrestia Forbes (Asia: Maharashtra)
Macrotyloma (Wt. & Arn.) Verdc. (Asia: only in cultivation)
Medicago Linn. (Asia: USSR)

Nogra Merrill (Asia: Maharashtra)
Ougenia Benth. (Asia)
Paracalyx Ali (Asia: India and Pakistan)
Pseudarthria Wight & Arn. (Asia)
Psophocarpus Necker ex DC. (Asia)
Pueraria DC. (Asia)
Pycnospora R. Br. ex Wt. & Arn. (Asia, Ceylon, China)
Shuteria Wight & Arn. (Asia: Japan)
Taverniera DC. (Asia)
Macroptylium (Benth.) Urban (Asia)
Zornia Gmelin (Asia).

Cajanus DC.: Nine species of *Cajanus* DC. are found in Maharashtra, whereas its global distribution is not yet clear. Except one cultivated species, which is a native of the Congo (Africa), the rest are Asian species of Indian origin. Most of the Indian species were placed in genus *Atylosia* Wt. & Arn. which has been merged with *Cajanus* DC. by Van der Meusen (1985). Only *Cajanus goensis* Dalz. is endemic to Goa and Maharashtra, the rest are common in India, especially southwards of Mumbai.

Canavalia DC.: Willis (1982) and Mabberley (1987) list *Canavalia* DC. as of tropical American origin, with 31 species worldwide. Actually, *Canavalia* DC. is a corrupted form of a name of Indian origin. A species belonging to this genus is in HORTUS MALABARICUS (Vol. 8: 87-8, t. 45, 1688) under the local name "Ran-vel". This local name Ranvel was modified into a latinised generic name as "Ranavelia". However, the cartographic letter 'R' in HORTUS MALABARICUS was perceived as 'C' by Adanson (Familis des Plantes 2: 325 & 531, 1763) and the generic name *Canavali* Adanson resulted. Therefore, the name *Canavali* Adanson is perfectly of Indian origin, although the type species of this genus might be native to Brazil (S. America), as *Canavalia* DC. has been conserved against *Canavali* Adanson.

Canavalia stocksii Dalz. is morphologically more distinct than any other species in this genus, and requires a separate generic name. We propose a new generic name *Aemaredalzellia* S.M. Almeida & S. Dutta after M.R. Almeida who has conceived this concept and N.A. Dalzell who discovered this species, combining both the names in the generic epithet.

The following are the differences between *Canavalia* DC. & *Aemaredalzellia* S.M. Almeida & S. Dutta:

Canavalia DC.	*Aemaredalzellia* S.M. Almeida & S. Dutta
1. Stipules nearly 1.4-1.5 cm long.	1. Stipules less than 1 cm long.
2. Pods turgid, almost flat along the dorsal suture.	2. Pods not turgid, deeply double channelled along the dorsal suture.
3. Leaflets ovate.	3. Leaflets obovate.

Latin diagnosis:

Canavalia DC.	*Aemaredalzellia* S.M. Almeida & S. Dutta
1. Stipulae feve 1.4-1.5 centimetirum longus.	1. Stipulae brevis.
2. Legumen turgidus planus dorsalis suturalis.	2. Legumen non turgidus penitus duplex canaliculatus secus dorsalis sutura.
3. Foliolo ovatus.	3. Foliolo obovatus.

Clavulium Jungh: This monotypic genus has been revived by the first author (Almeida 1996-2001) on its distinct seed characters and differentiation in chemical contents. So far, this genus is found in Tropical Asia only, represented by *Clavulium laburnifolium* (Linn.) Almeida.

Clitoria Linn.: This genus of Tropical American origin, which has typical species of perennial climbing habit, has evolved as herbaceous annuals in India, especially in Maharashtra. *Clitoria ternatea* Linn., an extensive bushy climber was later discovered to be reduced in form, in the annual variety *pilosula* Baker with less prolific climbing habit, and later in erect annual forms *Clitoria annua* Graham (Syn. *C. biflora* Dalz.) and *C. annua* var. *sekharii* Almeida & Chaturvedi (probably *C. vaupelii* Dalz. & Gibs.). Recently, the first author has observed this variety occurring in Dediapada Taluka in Narmada district of Gujarat, which confirms its wide distribution in Gujarat from Mount Abu (from where *C. vaupellii* D. & G. was originally described) to Dediapada, which is almost on the border of the present Maharashtra.

Crotalaria Linn.: This genus is the most common among leguminous plants, widely distributed in the tropics and subtropics, and comprises more than 600 species. It is represented in India by 86 species, of which as many as 56 are listed from Maharashtra. Barring 11 species (7 Australian, 4 African), the remaining 45 are of Asian origin. *Crotalaria dubia* Graham ex Benth., *C. lutescens* Dalz., *C. orixensis* var. *waghii* Almeida & Almeida, *C. filipes* var. *panthakii* Almeida & Almeida, *C. stocksii* Bentham, *C. triquetra* Dalz. & *C. yasminii* Almeida & Almeida are so far known only from Maharashtra. Seeds of many species contain derivatives of alkaloidal monocrotalane base and are fatally poisonous to humans, particularly infants who enjoy playing with its rattling seedpods.

Desmodium Desv.: This is a large genus consisting of *c.* 300 species, mostly Asian and American in origin. About 42 species are found in India, of which 18 are reported from Maharashtra. At least 2 species in this genus are endemic to Maharashtra, namely *Desmodium alysicarpoides* Snaap van Meeuwen (Bombay Presidency) and *D. ritchiei* Sanjappa (Bombay Presidency).

Desmodium alysicarpoides Snaap van Meeuwen is a bridging species between *Alysicarpus* Desv. and *Desmodium* Desv. with some common characters of both. Van der Meeuwen (1962) keeps it in *Desmodium* Desv. whereas Thothatri and Pramanik (1987) created a new genus *Desmodiastrum* Thoth. & Pramanik to accommodate this together with *Alysicarpus racemosus* Benth. and *Desmodium rotundifolium* Baker. However, we feel this narrow concept is not fit for acceptance even at subgeneric level. The usual practice is to merge the genera if any intermediate species is found with circumscription characters of both.

Indigofera Linn.: This genus comprises 700 species distributed in Warm and Temperate regions of the world, out of which 50 are found in India and 37 taxa are represented in Maharashtra. The 4 endemic taxa are:

1. *Indigofera deccanensis* Sanjappa (Beed, Pune)
2. *I. santapaui* Sanjappa (Purandhar)
3. *I. trifoliata* Linn. var. *duthiei* (Drum. ex Naik) Sanjappa (Marathwada)
4. *I. trita* var. *purandharensis* Sanjappa (Purandhar)

Lepidocoma Jungh.: This is a segregate genus of *Flemingia* Roxb. ex Ait. & Ait., recently recognised and re-established by Almeida (1996-2001). Presently it contains 5 species in India, and 4 of these occur in Maharashtra. However, two species in this genus, namely *L. gracilis* (Mukh.) Almeida and *L. rollae* (Billore & Hemadri) Almeida are not sufficiently distinct from *L. neilgherrensis* (Cooke) Almeida to be retained as species or even subspecies, and we propose to merge them with *L. neilgherrensis* (Cooke) Almeida as varieties:

1. *Lepidocoma neilgherrensis* (Cooke) Almeida var. *gracilis* (Mukherjee) S.M. Almeida & S. Dutta (comb. et stat. nov.) [Basionym: *Moghania gracilis* Mukherjee, Bull. Bot. Soc. Bengal 6(1): 22-4, 1953].
2. *Lepidocoma neilgherrensis* (Cooke) Almeida var. *rollae* (Billore & Hemadri) S.M. Almeida & S. Dutta (comb. et stat. nov.) [Basionym: *Moghania rollae* Billore & Hemadri, Journ. Econ. Tax. Bot. 3: 617, 1982].

Mucuna DC.: Four species of *Mucuna* DC. have been recorded from Maharashtra. Two species, *M. atropurpurea* DC. and *M. gigantea* (Willd.) DC., that have been reported by Graham (1839), have not been collected by subsequent authors. Either they were overexploited in the past or they might have been mistaken identifications. Sanjappa (1992) gives their distribution as follows:

Mucuna atropurpurea DC. - Asia

M. gigantea (Willd.) DC. - Asia

Nogra (Baker) Merrill: *Galactea simplicifolia* Dalzell happens to be a later homonym. Baker (in Hk. f., 1876) realising that Dalzell's species did not belong to *Galactea* P. Browne, removed it from that genus and placed it under *Grona* Baker, providing it with a new specific epithet after its original discoverer. Merrill (1935) realising that the generic name *Grona* had been already used for a different generic concept and that Baker's name was a later homonym, changed the name proposed by Baker from *Grona* to *Nogra*.

Ophrestia (Dalz.): *Glycine pentaphylla* Dalz. was also found to be not within the generic circumscription of *Glycine*, and Verdcourt (1970) has suggested shifting it to Dalzell's subgenus that was raised to generic status by Forbes, as *Ophrestia pentaphylla* (Dalz.) Verdcourt.

Nogra (Baker) Merrill and *Ophrestia* (Dalz.) are both monotypic genera, represented in Maharashtra by two endemic species.

Smithia Ait.: This is mainly an Afro-Asian genus with *c.* 15 species in India, 13 of them in Maharashtra. Nine of the 13, namely *Smithia gracilis* Benth., *S. bigemina* Dalz., *S. capitata* Dalz., *S. conferta* Sm. with *S. conferta* var. *geminiflora* Cooke, *S. pycnantha* Benth. ex Baker, *S. salsuginea* Hance, *S. setulosa* Dalz., *S. flava* Dalz., *S. hirsuta* Dalz. are endemic to Maharashtra. Surprisingly, except *S. sensitiva* Ait., none of these abundant herbs of the monsoon were recorded by John Graham, though many of them occurred at Khandala where he lived all his life.

Tephrosia Pers.: This is a large genus consisting of 400 species distributed in tropical regions. India has 25 species, out of which 14 are found in Maharashtra. Only two species, namely *T. sara-almeidii* Almeida and *T. strigosa* (Dalz.) Sant. & Maheshwari, are endemic to Maharashtra. *T. sara-almeidii* Almeida was collected from Sewri area in Bombay (=Mumbai), which is now thickly populated resulting in the destruction of the habitat. Our attempts to relocate it in its type locality have not met with success. It is more than likely that it is no longer extant in the wild.

T. strigosa (Dalz.) Santapau & Maheshwari is unique in the genus in having unifoliolate leaves. Dalzell (1850) had placed it in a new genus *Macronyx* Dalz. In addition to its unifoliolate leaves, it has a flat pod, which is attached to a long hairy pedicel. The parallel venation of its leaflets is also an unmistakable character and it may be worthwhile to retain this species in its separate generic identity as conceived by Dalzell.

Vigna Savi: This is also a large genus with 150 species of Old World Tropics. Nine species are found in India and 18 intraspecific taxa are represented in Maharashtra. The following endemic species are found in Maharashtra:

V. dalzelliana (O.K.) Verdc.

V. grahamiana (W. & A.) Verdc.

V. khandalensis (Sant.) Raghavan

V. vexillata var. *sepiaria* (Dalz.) Benth.

V. vexillata var. *stocksii* (Benth.) Baker

Except for *V. adenanthus* (Mayer) Marechal, which is of African origin, all species found in Maharashtra are Asian in origin. Most of them are known for their edible pulses. *V. radiata* and *V. vexillata* and their varieties are commercial crop plants.

Caesalpiniaceae R. Br.

(Subfamily Caesalpinoidae of Fabaceae)

This is one of the segregate families of Fabaceae Lindley (and sometimes called as Subfamily Caesalpinoidae). It has 3 endemic species from Maharashtra, namely *Bauhinia foveolata* Dalz. (*B. lawii* Benth. ex Baker), *Cassia kolabensis* Kothari *et al.* and *Moullava spicata* (Dalz.) Nicolson (*Wagatea spicata* Dalz.).

Cassia Linn.: This genus is the largest with 535 species in the world and 24 species in India, of which 23 are found in Maharashtra. There are three clearly distinguishable subgenera, as follows:

1. *Cassia* species with strap-shaped (flat) pods, e.g. *Cassia siamea* (*senna* of American authors).
2. *Cassia* species with cylindrical pods, e.g. *Cassia fistula* Linn. with transverse pods with circular septa – i.e. *Cassia* Linn. proper (*sensu stricto*).
3. *Cassia* with cylindrical pods with vertical ridges (*C. orientalis* Pers.).

Cassia surattensis Burm. f. was described from the East India Company's herbarium in Surat. But the plant is common in coastal areas of Mumbai, especially Malabar Hill and Khandala Hill. *C. uniflora* Mill. is the most recent introduction and has been collected from Pune and Wai-Panchgani area by the first author.

Tamarindus Linn.: This is a monotypic genus with *Tamarindus indica* Linn. as the only recognised species. The plants occur wild in the tropical African region, but the species is described based on the figure in HORTUS MALABARICUS and its generic name is coined from the Arabic "Tamar-e-Hind" (Tamarind) meaning the date (Khajur) of India. It is said that initially the fruit was brought by Arab traders for marketing in India. The port where they were off-loaded was called 'Chinch Bunder' (Chinch = Tamarind in Marathi) and they were sold in 'Tamarind Lane' in the Fort area, opposite the General Post Office in Bombay city. Plants of this species are generally found near human habitation and are artificially planted. The plant rarely survives naturally in the wild. The cotyledons and young saplings of this plant are food items of insects and other animals.

Mimosaceae R. Br.
(Subfamily Mimosoidae of Fabaceae).

Acacia Mill.: This is a large genus clearly distinguishable in two groups or subgenera. In Maharashtra there are 33 species. Among these are 4 Australian species with phyllodes and without spines. The remaining species are of Indo-American and African origin, generally with spines and without phyllodes. *Acacia canescens* Graham ex Gamble seems to have been based on Graham's collection from the erstwhile Bombay Presidency. However, it is a rare species and not much known in Maharashtra. No endemic species has been reported from Maharashtra. Australian *Acacia auriculiformis* A. Cunh., *A. longifolia* Willd. and *A. mangium* Willd. are used for energy plantations (presumed to be useful for fuel when the conventional energy resources get exhausted) as fast growing trees. There are 4 American species, 7 African species and 21 species of Indian origin.

Calliandra Bentham: This genus is represented by 5 species in Maharashtra, 4 of them are of American and 1 of Asian origin, but none from India. All the species are exotic and found only under cultivation, none are naturalised. Although many saplings are found under the flowering shrubs, hardly any survive unless they are replanted and looked after. Species recorded from cultivation are: *Calliandra selloi* (Spr.) McBride, *C. emarginata* (Humb. & Bonpl. in Willd.) Benth., *C. haematocephala* Hassk., *C. inermis* (L.) Druce and *C. surinamensis* Benth.

Entada Adanson: *E. rheedei* Spr. is the largest Asiatic climber of Indian forests, common in Maharashtra, and has the largest pods. Its seeds are about 5 cm in diameter and 1.5 cm thick.

Leucaena Benth.: *L. leucocephala* (Lamk.) de Wit. is a native of Mexico (America), but one of its fast growing hybrids, developed in Australia and New Zealand, is distributed all over the world (including India) and is used on a massive scale for social forestry in Maharashtra. The species is known in Maharashtra from the time of Graham (1839).

Mimosa Linn.: There are 4 species of *Mimosa* Linn. in India. Three of these are Asian in origin and the most common and abundant one, *Mimosa pudica* Linn. locally called

"Lajvanti" or "Lajalu", is surprisingly said to be of American origin. It existed in India prior to Graham (1839) and was used in traditional Indian medicine (Ayurveda) especially for suppressing hydrocele.

Crassulaceae DC.

Crassulaceae DC. is a family of succulent plants and its principal genus in Maharashtra is *Kalanchoe* Adanson. Genus *Kalanchoe* has about 125 species distributed in the tropics, with many of them grown in India in gardens as succulent plants. 13 species have been recorded from Maharashtra — 7 indigenous ones growing wild and 6 cultivated in gardens as exotic ornamentals. *K. bhidei* Cooke and *K. olivacea* Dalz. are considered as endemic to Maharashtra. *K. ritchiana* Dalz. earlier published as endemic to Bombay Presidency has been merged with *K. glandulosa* Hochst., an Abyssinian species, presently reduced to a variety of *K. lanceolata* (Forsk.) Pers., another Abyssinian taxon.

To our knowledge, except for *K. pinnatum* (Lamk.) Pers. which is a species of wet habitat along the sides of rivers and streams, mostly in shady places, all the other xerophytic species prefer dry elevated areas and are found around Moghul forts and old Abyssinian settlements. They are also African introductions in these areas and may prove to be conspecific with certain older Abyssinian species described earlier, especially if it is ascertained that these species and their seeds form the food of migrating birds, and there are any chances of their being introduced through these avian migrants. Only careful scrutiny and taxonomic verifications will make this clear.

Myrtaceae Juss.

This family (*senso lato*, including Barringtoniaceae and Lecythidaceae) is represented in Maharashtra by nearly 40 species. There are 14 species of Australian origin (12 species of *Eucalyptus* L'Heritier, 1 of *Callistemon* R. Brown and 1 of *Melaleuca* Linn.), 5 species of American origin (2 species of *Gustavia* Linn., 1 of *Pimenta* Mill. and 2 of *Psidium* Linn.), and 3 species of *Barringtonia* Forst. & Forst. and 16 species of *Syzygium* Gaertner of Asian origin. A species of *Myrtus* L. (*M. communis* Linn.) is probably the one European member in Maharashtra, whose country of origin is not known.

Eucalyptus L'Heritier: Australian *Eucalyptus* spp. earlier came to India for their useful oil much valued in medicine and as an insect repellent. They are now valued for yield of paper pulp. *Eucalyptus* is thought to deplete the water table, but this belief is without scientific support. The argument is put forward that the 14 species found in the Nilgiris of south India have lowered the water table in the famous hill station of Ooty. The fact remains that the commercial propagation of *Eucalyptus* in the Nilgiris has resulted in the clearing of forests to plant it, thus opening the canopy and allowing sunlight to reach the ground and evaporate the water from the soil, ultimately resulting in lowering the water table. In our opinion, the blemish attributed to *Eucalyptus* trees is unfounded.

Syzygium Gaertner: Out of the 16 species of *Syzygium* Gaertner, 6 are common to India and Sri Lanka, and one each to India and Java, and India and Malaya. The remaining 50% (8 species) are restricted to India, and none is actually apparently endemic to Maharashtra.

Syzygium montana Wt. was found to be a later homonym and it was renamed *S. gadgillii* Almeida by the first author, but that name now has to be relegated to synonymy, as the species had already been renamed *S. tamilnadensis* Radhakr. & Chithra (in Nair & Henry, Tamil. St. Fl. Anal. 1: 158, 1983), which has priority.

Melastomataceae Juss.

This family is represented by one endemic species *Sonerilla scapigera* Dalz. in Maharashtra.

Lythraceae St. Hill.:

Ammania multiflora Roxb. forma *uniflora* Blatter, *A. nagpurensis* Matthew & Nair and *Rotala ritchiei* (Cl.) Koch. are the three endemic taxa belonging to this family, found in Maharashtra.

Passifloraceae Juss. ex Kunth.

This family is represented in Maharashtra by two genera. *Adenia* Forsk., with a single species is found in the wild and is common in Asia and Africa. The other genus, *Passiflora* Linn. which has 15 species is entirely exotic, with one species from Africa and the rest from America. *Passiflora foetida* Linn. is found in the wild as a climber.

Cucurbitaceae Juss.

This family is represented in Maharashtra by 58 species belonging to 21 genera. The following taxa are recorded as endemic to Maharashtra:

1. *Kedrostis courtallensis* var. *deshmukhii* (Alm. & Alm.) M.R. Almeida, S.M. Almeida & S. Dutta [Basionym: *Cerasiocarpum bennettii* (Miq.) Cogn. ex DC. var. *deshmukhii* Almeida, Fl. Maharashtra 2: 311, 1998.]
2. *Dicoelospermum ritchiei* Cl.
3. *Coralocarpus conocarpus* (D. & G.) Hk. f.
4. *Praecitrullus fistulosa* (Stocks) Pungalo

Begoniaceae Agardh.

This family has a single genus with 8 species in Maharashtra, of which 4 are endemic. All wild species grow above 1,000 m altitude in the Western Ghats except *B. crenata* Dryand. which is sometimes found at much lower elevations. A number of species are grown in gardens in Mumbai and Pune, many of them remain to be properly identified. Endemic species are: *B. concanensis* DC., *B. integrifolia* Dalz., *B. prixophylla* Blatter and *B. trichocarpa* Dalz.

Apiaceae Lindley

There are 18 genera and 32 species in Maharashtra. 13 genera are represented by a single species. There are 11 endemic species in Maharashtra, which are listed below:

Heracleum aequilegifolium Cl.
H. dalgadianum S.M. Almeida
H. grandis (D. & G.) Mukherjee
Peucedanum dhana var. *dalzellii* Cl.
Pimpinella adscendens Dalz.
P. rollae Billore & Hemadri
P. tomentosa Dalz.
P. wallichiana Miq.
P. wallichiana var. *katrajensis* (Rolla & Hem.) Alm.
Pinda concanense (Dalz.) Constance & Mukhopadhaya
Polyzygos tuberosa Dalz.

Rubiaceae Juss.

Family Rubiaceae Juss. is represented in Maharashtra by 131 taxa belonging to 49 genera. There are 6 American, 5 African, 2 Australian and 118 Asian taxa with 72 of Indian origin.

In recent years, Family Rubiaceae has undergone many nomenclatural changes. Genera *Benkera* Adanson, *Catunaregam* Adanson ex Wolf., *Tamilnadia* Tiruveng., *Ceriscoides* (Hook. f.) Tiruveng., *Euclinia* Salisbury, *Haldina* Ridsdale, *Neanotis* Lewis, *Neolamarkia* Bosser, *Neonauclea* Merrill, *Ochreinauclea* Ridsdale & Brink. f., *Psydrax* Gaertn., *Tricalycia* A. Rich. have been revived during the last three decades.

The following endemic species from Maharashtra have been recorded:

Kohautia nagpurensis (Bruce & Haines) Sant.
Neanotis carnosa (Dalz.) Lewis
N. decipiens (Hk. f.) Lewis
N. lancifolia Lewis
N. ritchiei (Hk. f.) Lewis
N. sahyadrica Billore & Mudaliar
Oldenlandia stocksii Hk. f. & T.
O. talbotii (Balakr.) Almeida
Pavetta concanica Bremek.
P. crassicaulis Bremek.
P. siphonantha Dalz.

P. stocksii Bremek.
Psychotria dalzellii Hk. f.

Neanotis Lewis: This genus has 28 spp. in Maharashtra mostly of Asian and Australian origin. The generic name *Anotis* DC. is restricted to New World species, and Old World species have been transferred to a new genus *Neanotis* Lewis. 13 species of the new genus *Neanotis* are reported from Maharashtra, out of which 5 are endemic and are given below:

Neanotis carnosa (Dalz.) Lewis
N. decipiens (Hook. f.) Lewis
N. lancifolia Lewis
N. ritchiei (Hook. f.) Lewis
N. sahyadrica Billore & Mudaliar

Oldenlandia Linn.: There are 300 species of this genus distributed in the Tropics. Seventy species of this genus occur in India and 15 taxa are found in Maharashtra. All species of *Oldenlandia* Linn. from Maharashtra are of Asiatic origin. Some authors merge *Oldenlandia* Linn. with *Hedyotis* Linn. However, there is more or less consensus among world taxonomists that they should be kept separate even on minute differences in generic characters, as the bulk of the total species is very large. Of the 15 species recorded from Maharashtra, 2 are endemic, namely *O. stocksii* Hook. f. & Thoms. and *O. talbotii* (Balakrishnan) Almeida.

Pavetta Linn.: The 8 spp. recorded from Maharashtra are all Asiatic in origin, and of them 4 are endemic to Maharashtra. Many of them have very restricted distribution. A few species are hosts for some special type of pathogenic fungi that infect them profusely making them easily recognisable. Species endemic to Maharashtra are: *Pavetta concanica* Bremek., *P. crassicaulis* Bremek., *P. siphonantha* Dalz. and *P. stocksii* Bremek.

Asteraceae Dumort. (= **Compositae** Giseke)

Asteraceae is one of the largest families in Maharashtra with 224 species, belonging to 103 genera. There are 17 European, 6 Australian, 3 African, 44 American and 131 Asian species found in Maharashtra. There are 78 species which are found only in India and 15 species are endemic to Maharashtra. *Blumea* DC., *Baccharoides* Moench. and *Senecio* Linn. are three large genera in Compositae. *Acanthospermum* Schrank., *Achillea* Linn., *Adenoon* Dalz., *Aster* Linn., *Bellis* Linn., *Blepharisperma* DC., *Brachycome* Cass., *Caesulia* Roxb., *Calendula* Linn., *Callistephus* Cass., *Carthamus* Linn., *Centaurea* Linn., *Centipeda* Lour., *Chromalaena* DC., *Chrysanthellum* A. Rich., *Cirsium* Mill., *Coreopsis* Linn., *Crassocephalum* Moench., *Dichrocephala* L'Herit., *Dicoma* Cass., *Echinops* Linn., *Eclipta* Linn., *Elephantopus* Linn., *Enhydra* Lour., *Epaltes* Cass., *Felicia* Cass., *Flaveria* Juss., *Gamochaeta* Weddell, *Gerbera* Linn., *Glossocardia* Cass., *Glossogyne* Cass., *Goniocaulon* Cass., *Grangea* Adans., *Guizotia* Cass., *Lactuca* Linn., *Lamprachaenium* Benth., *Melampodium* Linn., *Mikania* Willd., *Montanova* Llave & Lex., *Nanothamnus* Thoms., *Parthenium* Linn., *Rudbeckia* Linn., *Sclerocarpus* Jacq., *Scorzonera* Linn., *Siegesbeckia* Linn., *Solidago* Linn., *Taraxacum* Wiggers, *Tragopogon* Linn., *Tridax* Linn., *Verbesina* Linn., *Vittadinia* A. Rich. and *Wollastoria* DC. ex Decaisne are 52 genera, each with a single species in Maharashtra.

Asteraceae has 2 genera, 14 species, 3 varieties, and 2 formas endemic to Maharashtra, which are given below:

Adenoon indicum Dalz. (gen., sp.)
Artemisia japonica var. *purandharensis* Alm. (var.)
Baccharoides lilacinum (D. & G.) Almeida (sp.)
B. hookeri (Hk. f.) Almeida (sp.)
B. ritchiei (Hk. f.) Almeida (sp.)
Blumea venkataramanii Rao & Hem. (sp.)
Cyathocline lutea Wt. (sp.)
Hymenatherum hewrensis (Dalz.) Almeida (sp.)
Kleinia balsamica (Dalz. & Gibs.) Almeida (sp.)
Lamprachaenium microcephalum (Dalz.) Benth. (gen. & sp.)
Pentanema cernua (Dalz.) Ling. (sp.)

Senecio arachnoides (Cl.) Almeida (sp.)
S. dalzellii Clarke. (sp.)
S. gibsonii Hk. f. (sp.)
S. lanuginosa forma *lapsana* Alm. (forma)
S. lanuginosa var. *aclandii* Almeida (var.)
S. lanuginosa var. *tomentosa* (Wt.) Almeida (var.)
S. lanuginosa var. *tomentosa* forma *cordifolia* Alm. (forma)
Tricholepis montana D. & G. (sp.)

Lamprachaenium Benth.: *Decaneuron microcephalum* Dalz. has been shifted to the monotypic genus *Lamprachaenium* by Bentham in 1893. In our opinion this species belongs to *Baccharoides* Moench. and does not deserve generic status. Except for its scanty pappus, it fits perfectly in genus *Baccharoides* Moench. We propose a new combination under genus *Baccharoides* Moench. as *B. microcephalum* (Dalz.) Almeida, Almeida & Dutta. [Basionym: *Decaneuron microcephalum* Dalz., Kew J. Bot. 3: 231, 1851].

Plumbaginaceae Juss.

Dyerophytum arabicum (DC.) Almeida (Syn. *Vogelia arabica* Boiss. ex DC., *Vogelia indica* Gibs. ex Wt.).: Now distributed in Maharashtra, Karnataka, Gujarat and Rajasthan, also known from Arabia (Oman) and the island of Socotra, this species was discovered from Hanuman Ghat by Alexander Gibson who proposed a new name *Vogelia indica* which was published in Wight's ICONES in 1842, with the remark that it is related to the long lost Cape species (*V. arabica* Boiss. ex DC.). The first author had communicated the correct name of this species to Dr. Henry Noltie but he prefers to call it *Dyerophytum indicum* (Stocks ex Wt.) Kuntze. Strictly speaking, there are a number of anomalies in Dr. Noltie's accepted name. The name of Wight who wrote the description or sketched the figure now forms part of the original protologue, but the authority goes to the author who first published the name, and modern taxonomists put the name of Wight only in parenthesis before Otto Kuntze since it was transferred to the new genus *Dyerophytum* O. Kuntze. Since the name was proposed by Gibson it should be referred to him, and Wight was perfectly correct in calling it *V. indica* Gibson ex Wight, irrespective of who contributed to the protologue for its valid publication.

About its identity, we would submit that the plant is actually not a new discovery but the same Arabian species presumed lost by Gibson, which is described in De Candolle's PRODRUMUS (1828) by Boissier from Arabia.

In the history of many Deccan forts, species described as new from time to time have turned out to be introductions from far and wide by the rulers of these forts (e.g. *Frerea indica* Dalz., *Rhamnus purandharensis* Bhandari, *Vogelia indica* Gibson ex Wt.). They are suspected to be introductions from Arabian countries by Moghul rulers of the past. Very often they were presumed to be new species and assigned the status of a new genus, because the other related species of the taxon were unknown in the region. *Dyerophytum arabicum* (Boiss. ex DC.) Almeida as conceived here is a classic example.

Myrsinaceae R. Br.

This is a small family with 4 genera and 8 species in Maharashtra. The largest genus in the family is *Embelia* Burm. f., with 3 species known from the time of Graham (1839). Nomenclature of species of *Embelia* in Maharashtra was not clear and for *E. ribes* Burm. f. there is still a shadow of doubt. More literature search and proper typification can clarify the nomenclature of this species.

Embelia tsjarium-cottam DC. in Cooke's Flora was a misapplication of the name, and actually refers to *Embelia basal* (R.& S.) DC. The real *E. tsjarium-cottam* (R. & S.) DC. may be a species from Euphorbiaceae, now recognised as *Antidesma ghassembilla* Gaertn. The correct identity of this species is not clear despite

Dr. G. Panigrahi identifying this species as a Myrsinaceous plant and the presence of a good specimen in Central National Herbarium, Kolkata.

Another *Embelia* species in Maharashtra was long known under a wrong name as *E. viridiflora* Schef. There existed two earlier binomials for this species, one from Graham's Catalogue (1839) and still earlier from Dennstadt's names for plants in HORTUS MALABARICUS. The correct name for this species is *Embelia drupacea* (Dennst.) Almeida & Almeida. (See J. Bombay nat. Hist. Soc. 90: 420, 1993).

Ebenaceae Gurke

This is a small family in Maharashtra with 19 species, all kept in one genus *Diospyros* Linn. by modern taxonomists. *Maba* Forster & Forster was maintained as a separate genus by earlier botanists on the basis of trimerous arrangement of petals, *Diospyros* flowers being pentamerous. It so happens that there are some bridging species in this family which have 3-4 or 5 petals found in flowers of the same tree and therefore some recent authors had merged these genera into a single genus, which is followed by late Rev. Fr. Cecil Saldanha in his FLORA OF HASSAN DISTRICT (1976). As mentioned earlier, a different view has been adopted by Thothatri and Pramanik (1987) for some species bridging *Alysicarpus* Desv. and *Desmodium* Desv., where they created a new generic name for these bridging species. We feel that *Maba* Forst. & Forst. should be retained as a separate genus, as bridging species are a normal phenomenon in the evolution of taxa.

Apocynaceae Juss.

The family Apocynaceae Juss. has 61 species and infraspecific taxa in Maharashtra belonging to 30 genera, 17 of these genera being monotypic. The family has 16 American, 3 African and 1 European species, and in the State, 39 species are of Asian origin, 21 being Indian and 2 yet to be ascertained regarding their continents of origin.

Periplocaceae Schltr.

This is a segregate family from Asclepiadaceae R. Br., bridging Apocynaceae Juss. and Asclepiadaceae R. Br. It has 5 species belonging to 3 genera in Maharashtra, two genera being of Indian origin and one genus with 2 species from Africa.

Asclepiadaceae R. Br.

Asclepiadaceae is one of the larger families in Maharashtra with 86 taxa (10 African, 2 American, 1 Australian, 73 Asian), belonging to 34 genera. Out of the 73 Asian species, 60 are Indian in origin. The family has a large percentage of endemics in Maharashtra which are listed below:

Brachystemma malvanensis Yadav *et al.*
B. naorojii Tetali *et al.*
Ceropegia attenuata Hk.
C. evansii McC.
C. huberi Ansari
C. jainii Ansari & Kulk.
C. kulkarnii Yadav *et al.*
C. lawii Hk. f.
C. lawii var. *maccanii* (Ansari) Almeida
C. lawii var. *panchganensis* (Blatt. & McC.) Almeida
C. lawii var. *wadhwii* Alm.
C. mahabalei Hem. & Ans.
C. media (Hub.) Ansari
C. noorjahanii Ansari
C. oculata Hk. f.
C. odora Nimmo ex Hk. f.
C. rollae Hemadri
C. santapaui Wadh. & Ans.
C. vincaefolia Hk.
Desmidorchis dalzellii Almeida
Dregea lanceolata (Cooke) Sant.
Gymnema khandalensis Sant.
Heterostemma dalzellii Hk. f.
Hoya retusa Dalz.
Oianthus deccanensis Talbot
O. disciflorus Hk. f.
O. urceolatus (Dalz.) Benth.
Seshagiria sahyadrica Ans. & Hem.
Tylophora dalzellii Hk. f.

In this very important family there is a high percentage of endemism in Maharashtra (29 out of 86 taxa are endemic to Maharashtra). The highest generic endemism in Maharashtra is observed in the genus *Ceropegia* Linn.: of 33 species recorded in India, 24 are found in Maharashtra, 15 of them being endemic to the State. *Brachystemma* R. Br., *Dregea* Meyer, *Gymnema* R. Br., *Desmidorchis* Ehrenb., *Heterostemma* Wt. & Arn., *Hoya* R. Br., *Oianthus* Benth., *Seshagiria* Ansari & Hemadri, *Tylophora* R. Br. are some of the other genera endemic to Maharashtra.

Gentianaceae Juss.

This family has contributed 5 endemic taxa to the flora of Maharashtra: *Canscora concanensis* Clarke, *C. decurrens* Dalz., *C. diffusa* (Vahl) R. Br. var. *tetraptera* Naik & Pokle, *C. khandalensis* Santapau and *C. pauciflora* Dalz.

The only species assigned to *Centaurium* Hill., a predominant genus from the northern hemisphere, occurring in Maharashtra, has been named as *Centaurium meyeri* (Bunge) Druce by C.R. Jadhav in FLORA OF MAHARASHTRA (2001, Dicot. p. 405). The correct name for this species under that genus is *C. centauroides* (Roxb.) Rao & Hemadri, which was published from the same place where Jadhav worked, and has priority of publication.

Acanthaceae Juss.

This family too is one of the larger families in Maharashtra. It has 4,300 species belonging to 346 genera distributed throughout the world. India has about 199 species belonging to 58 genera. In Maharashtra, 204 species and infraspecific taxa are found.

Aechmanthera gossypina (Nees) Nees has been recently reported as a cultivar.

Andrographis Wall. ex Nees: Out of 3 taxa belonging to this genus reported from Maharashtra, only one — *A. paniculata* is clearly known to us. It is truly wild in Vidarbha, elsewhere it is only found under cultivation. *A. neesiana* Wt. var. *producta* Cl. and *A. viscosula* Nees var. *explicata* Cl. have been reported by Clarke in Hooker's FLORA OF BRITISH INDIA, from Maharashtra.

Aphelandra R. Br.: Of this genus, 5 species are found under cultivation in Maharashtra along with *Kuestera* (*K. aurantiacea* Regel) which was also placed under *Aphelandra* R. Br. by some authors. All the 6 taxa are of S. American origin, coming from West Indies, Brazil and Mexico.

Genus *Beloperone* Nees, of which three species are cultivated in Maharashtra, is also of S. American origin.

Asystasia Blume: This genus has 4 taxa in Maharashtra, all of Asian origin, and now believed to be widely distributed in India.

Barleria Linn.:This genus is represented in Maharashtra by 18 species. All except two are Asiatic species. *B. prionitis* Linn., the Vajradanti of Ayurveda, is of African origin with Asian distribution in Egypt-Arabia and India, and *B. lupulina* Lindl. is from Mauritius. *B. gibsonides* Blatter, *B. gibsonii* Dalz., *B. involucrata* var. *clavata* Dalz., *B. lawii* T. Anders. and *B. pratensis* Sant. are endemic to Maharashtra.

Blepharis Juss.: This genus is now represented in Maharashtra by 2 species. The third has been placed in a new genus *Cynarospermum* Vollasen as *C. asperrimum* (Nees) Vollasen.

Bremekampia Sreemadhavan happens to be the correct generic name for *Haplanthus* O. Kuntze. *Carvia* Bremek., *Nilgirianthes* Bremek., *Pleocaulis* Bremek., *Thelepaepale* Bremek. and *Mackenzia* Bremek. are some of the new genera proposed by Bremekamp (1944), and have been used by Indian taxonomists but rejected elsewhere, although some of them have very good morphological distinguishing characters to support their segregation. For example, the members of genus *Pleocaulis* Bremekamp have a number of shoots springing up from a rhizomatous perennial root-stock, with scarce or no branching.

Nilgirianthus Bremek. is a segregated genus from *Strobilanthus* Bl., represented in Maharashtra by 9 species. Only two endemic species from the former Bombay Presidency, namely *N. halbergii* (Blatter) Almeida and *N. membranaceus* (Talbot) Bremek. are outside the limits of the present Maharashtra State.

Pleocaulis reticulata (Stapf.) Almeida and *P. ritchiei* (Clarke) Bremek. are two endemic species of this genus found in Maharashtra. The occurrence of *P. sessilis* (Nees) Bremek. which has been reported under *Strobilanthus sessilis* Nees, a south Indian species, is doubtful.

Pachystachys Nees is represented by 2 exotic S. American species under cultivation.

Dicliptera Juss.: This genus in Maharashtra is represented by 10 taxa, 7 of them assigned to species rank, but some of them might have to be reduced to lower ranks. *Dicliptera ghatica* Sant., *D. leonotis* Dalz. and *D. nasikensis* Lakshminar. & Sharma are endemic to Maharashtra. *Dischoriste dalzellii* (T. And.) O. Kuntze is also an endemic species in Maharashtra.

Eranthemum Linn.: There are 10 species of this genus. All are of Indo-Malayan origin, except *E. cooperi* Hook. which is a native of New Caledonia. Seven species from Maharashtra, which were earlier under this genus, are now placed in *Pseudoeranthemum* Radlk. and are natives of Malacca, Phillippines, Melanesia, India and Pacific Islands.

Fittonia Coem.: Three species of this genus, cultivated in gardens perhaps require reconsideration regarding their taxonomic status. They all come from Peru in S. America.

Graptophyllum Nees: This genus, members of which are found only in cultivation in gardens, is from Australia and New Guinea.

Gymnostachyum T. Anders.: Three species are found in Maharashtra, *G. glabrum (*Dalz.) T. Anders. is endemic to Maharashtra and the other two are widely distributed in Asiatic countries.

Hemigraphis T. Anders.: There are 5 species of this genus, all of Asiatic origin.

Hypoestes lanata Dalz. is a rare endemic species of Maharashtra.

Hygrophila R. Br.: Presently, this is an aggregate genus comprising *Cardanthera* Benth., *Synnema* Benth., *Asteracantha* Nees & *Physochilus* Nees. There are 9 taxa of this genus, belonging to 8 species, presently found in Maharashtra. *Hygrophila anomala* (Blatt.) Almeida is endemic to Maharashtra. The type, however, is missing, and materials in Blatter Herbarium are unseparable from where the taxon has originated. It is most likely to be conspecific with some other species. It is also possible that the identity of the other *Cardanthera* species being questionable, and Blatter realising the mistake has named this one with a substitute name. It is said to be allied to *C. pinnatifida* Benth. and the specific epithet *anomala* suggests that it is unique in *Cardanthera* Benth. *Hygrophila erecta* (Burm. f.) Hochr. is based on Rheede's figure in HORTUS MALABARICUS ("Nir-schulli" 2: 89-90, 1679) and has been a source of misidentification for a long time. Presently, it is identified as *H. ringens* (L.) R. Br. The correct name for 'Talimkhana' is *Hygrophila schulli* (Buch.-Ham.) Almeida & Almeida under genus *Hygrophila* R. Br. However, many taxonomists are used to treating it under the later synonym *H. auriculata* (Schum.) Heine. *Hygrophila stocksii* T. Anders. is endemic to Konkan.

Justicia Linn.: Some authors recognise this genus *sensu stricto*, as an aggregate genus, but many taxonomists in India recognise *Adhatoda* Medic., *Justicia* Linn. and *Rostellularia* Reichb. as segregate genera. *Adhatoda* Medic. is an untenable monotypic genus. *Justicia* Linn. is represented in Maharashtra by 7 species, most of them being of Asian origin. *Rostellularia* Reichb. in Maharashtra is represented by 13 species, mostly of Asian origin. *Rostellularia heterocarpa* (T. Anders.) Almeida is reported from Maharashtra by Cooke (1904) under *Justicia heterocarpa* T. Anders. and *R. heterocarpoides* (Blatt.) Almeida is described by Blatter (1930) under *J. heterocarpoides* Blatt. and is an endemic species of Maharashtra. Perhaps what is wrongly identified by Cooke as *J. heterocarpa* T. Anders., an Abyssinian species, has been renamed as *J. heterocarpoides* Blatter, by its author. A study of the types is required to settle the confusion.

Digera Nees is represented by a single species from Bolivia and *Jacobinia* Nees by three species from S. America. All four taxa are cultivated in Maharashtra. Some taxonomists merge *Jacobinia* Nees under *Justicia* Linn.

Lepidagathis Willd.: This genus, represented in Maharashtra by 13 spp., has a high percentage of endemism. The endemic species are *L. clavata* Dalz., *L. lutea* Dalz., *L. mites* Dalz. and *L. trinervia* var. *naikii* Alm. The type of *Lepidagathis bandraensis* Blatter is not represented in Blatter Herbarium and later taxonomists have not named any specimen as that species. There are a number of specimens of *L. trinervia* Wall. ex Nees from Bandra and nearby areas in Mumbai, and perhaps what is identified as *L. trinervia* is actually *L. bandraensis* Blatt. and perhaps the typical *L. trinervia* is not found in Mumbai. Naik (1998) has described a variety without naming it, which Almeida (1996-2001) named as a new variety *naikii* after Professor Naik, perhaps this may be synonymous with *L. bandraensis* Blatt. Surprisingly, *L. bandraensis* Blatter has been reported by Bhandari (1978) from the Indian desert in Rajasthan. *Lepidagathis fasciculata* (Retz.) Nees (Syn. *L. goensis* Dalz.) is of an altogether different appearance, but with the common characters of the genus, such as presence of 4 stamens and recurved styles. However, it does not have spiny apices of leaves and is open to further investigation.

The correct name for *Mackenzia integrifolia* (Dalz.) Bremek. is *Leptacanthus integrifolia* (Dalz.) Almeida (Basionym: *Endopogon integrifolium* Dalz.) (for a detailed discussion see FLORA OF MAHARASHTRA, Vol. IV).

Neuracanthus Nees: This genus is represented in Maharashtra by two species. Probably, one of them, *N. sphaerastachys* (Nees) Dalz., is endemic to Maharashtra.

In Maharashtra, there are 3 species of *Peristrophe* Nees, one each of *Petalidium* Nees and *Phaulopsis* Willd., and two of *Phlogacanthus* Nees in Wall. There are 6 spp. of *Pseudoeranthemum* Radlk., all of them Asiatic in origin, and 3 spp. of *Ruellia* Linn. of S. American origin. There are 6 spp. of *Rungia* Nees, all of them Asiatic, of which *R. elegans* D. & G. is endemic to Maharashtra. There are two Asiatic spp. of *Staurogyne* O.K. and two of *Thelepaepale* Bremek. *T. ixiocephala* (Benth.) Bremek. is the type species of *Thelepaepale*. However, the second species has been placed in a new genus *Supushpa* Subramanian, which we find does not differ substantially enough to warrant a separate status from *Thelepaepale* Bremek.

There are 7 species of *Thunbergia* Retz., five of them being of Asian origin and two from Tropical Africa. Only one is found in the wild while the rest are exotic garden plants.

Avicenniaceae Endl. ex Schnitzl.

The family has two species of *Avicennia* Linn. Of them, *A. officinalis* Linn. is of Indian origin and *A. marina* (Forsk.) Vierh. of Arabian origin. *A. marina* (Forsk.) Vierh. is often referred to as *A. alba* Linn., but the white mangrove is not found in India.

Verbenaceae St. Hill.

This family has 72 species in Maharashtra, 18 of these being from S. America, 3 from Africa, 4 from Australia and 47 from Asia. Of these, 2 are shared with Africa and one with America. The genera in the family can be grouped as follows:

1. American genera: *Aloysia* Juss., *Citheroxylum* Linn., *Duranta* Linn., *Lantana* Linn. (p.p.), *Stachytarpheta* Vahl.
2. Asiatic genera: *Callicarpa* Vahl., *Congea* Roxb., *Gmelina* Linn., *Holmskeoldia* Retz., *Hymenopyramis* Griff., *Phyla* Lour., *Priva* Adans., *Symphorema* Roxb. and *Tectona* Linn. f.

Congea Roxb. and *Symphorema* Roxb. are sometimes placed in a separate family Symphoremataceae Tieghem.

Clerodendron Linn.: This is the largest genus with 25 species represented in Maharashtra (including 2 American, 4 African, 1 African and Australian, 1 from Mascaren Island).

Premna Linn.: It has 5 spp. in Maharashtra, 4 of them are native to India and 1 to northeast Australia, namely *Premna lignum-vitae* (Sch.) Piper. Both Clarke (var. *viburnoides*) and Haines (var. *gamblei*) have described it as variety of *P. latifolia* Roxb. and it is perhaps the plant D.G. Dalgado has described as *Viburnum foetidum* Wall. in FLORA OF GOA AND SAVANTWADI (1898) where it is very commonly cultivated. The leaves are used for lactogenic treatment by women after delivery.

Vitex Linn.: All 7 taxa are Asiatic with one coastal species, *Vitex trifolia* Linn., extending to Australia.

Labiatae Juss. (Lamiaceae Lindley)

This is also one of the larger families in Maharashtra with 100 species belonging to 27 genera. There are 83 species of Asian origin, followed by 4 Mediterranean, 1 African, 5 American, 1 European and 1 Australian. There are 11 endemic taxa, namely *Anisodilus adenanthus* Dalz., *A. carnosus* var. *eriocephalus* Cooke, *Eusteralis salicifolia* (Dalz.) Almeida (*Dysophylla salicifolia* Dalz.), *E. tomentosa* (Dalz.) Panigrahi, *E. tomentosa* var. *gracilis* (Dalz.) Bennett & Raizada, *Leucas deodokari* Billore & Hem., *Nepeta bombaensis* Dalz., *Nepeta hindoostana* (Roth.) Haines var. *woodrowii* (Cooke) Sant., *Plectranthes stocksii* Hk. f., *Pogostemon benghalense* (Burm. f.) O.K. var. *glaberrima* (Sant.) Sant. & Jain and *P. purpurescens* Dalz.

Coleus Lour.: This genus is separated from *Plectranthus* L'Herit. on the basis of stamens being free at the base and not united in bundles. Many recent authors consider this character variable and accept the aggregate generic name *Plectranthus* L'Herit.

Similarly, *Eusteralis* Raf. is the earliest name for the generic concept of *Dysophylla* Blume, which some authors merge with genus *Pogostemon* Desf.

Leucas Linn.: This is the largest genus in the family, with 21 spp. in the State, all of Asian origin.

Platostoma Beauv.: It is represented in Maharashtra by one species — *P. africana* Beauv. which is a native of Africa.

Salvia Linn.: This is a genus of universal distribution found in Asia, America, Australia, Europe and the Mediterranean region. Some species in Maharashtra are only found as cultivars.

Nyctaginaceae Juss.

This family is represented in Maharashtra by 4 genera and 11 species. Two genera — *Bougainvillea* Comm. ex Juss. (S. American) and *Mirabilis* Linn. (from Peru) are purely exotic. *Boerhavia* Linn. and *Pisonia* Linn. have a wider global distribution.

Boerhavia Linn.: *B. erecta* Linn. was first reported in India from Pondicherry as a new species under the name *B. punarnava* Saha & Krishnamurthy (1960). MRA collected it from Bombay city in the compound of Wadia Hospital, Parel in 1964. He first found it conspecific with *B. punarnava* Saha & Krishnamurthy, and later realised that it was an American weed *B. erecta* Linn. He studied the entire Indian collection belonging to genus *Boerhavia* Linn. in the herbaria of the Botanical Survey of India, and other herbaria and came to some interesting conclusions, as follows:

1. *B. punarnava* Saha & Krishnamurthy is synonymous with *B. erecta* Linn.
2. *B. repens* Linn. (*B. diffusa* L.) is a very variable plant with a lot of intermediates and cannot be segregated into varieties on any reliable character, as was done by Hooker (1885) in FLORA OF BRITISH INDIA.

3. The type of *Boerhavia crispa* Heyne cannot be traced and the identity of that species is not yet clear.
4. *B. fruticosa* Dalz. is an undeterminable species from Junnar (in Pune district). The only old specimen at Central National Herbarium, Kolkata identified as this species turned out to be *Siegesbeckia orientalis* Linn., a species of Asteraceae. All efforts to establish the correct identity of this species have failed.

Koppula Hemadri who worked for his doctorate degree in the Junnar area, thoroughly searched for this plant without any success and finally concluded that it is a misidentification of *B. repens* Linn. or *B. chinensis* (Linn.) Asch. & Swein, or for that matter, any other species like *Siegesbeckia orientalis* Linn. which has tuberculated fruit resembling that of *Boerhavia* spp. Dr. V.N. Naik, following some Western taxonomists, equates *B. fruticosa* Dalz. with an Abyssinian species *B. grandiflora* A. Rich., but this has no taxonomic basis.

Boerhavia helenae Schult which is known in the FLORA OF BRITISH INDIA as *B. verticillata* Hk. f. and reported from the Sindh area, is recorded by Naik (1998) from Marathwada (as a new record for Maharashtra) under *B. boissierie* Heimerl.

Amaranthaceae Juss.

Amaranthaceae Juss. in Maharashtra consists of 46 species belonging to 14 genera.

Alternanthera Forsk. and *Iresine* P. Browne are of Tropical American origin while the other 12 genera are of mixed distribution. Species of *Achyranthus* Linn., *Aerva* Juss., *Allmania* R. Br. ex Wt., *Cyathula* Blume, *Digera* Forsk., *Psilotrichum* Blume, *Pupalia* Juss. and *Trichuriella* Bennett are of Asian origin. Species of *Aerva* Forsk., *Amaranthus* Linn., *Celosia* Linn., *Nothoserua* Wight are found in other continents besides Asia.

Amaranthus Linn.: This genus is represented in Maharashtra by at least 16 species, which are widely distributed across the globe, and for many species their country of origin is uncertain. Most of the species in Maharashtra and in India are exotic and are cultivated for vegetables. Most of them are found growing wild near human habitation, but rarely in forest areas.

Phytolaccaceae R. Br.

This family is represented in Maharashtra by two species, *Rivinia humilis* Linn. from Tropical South America and *Petiveria alliacea* Linn., native of Central America. Both are found in gardens.

Polygonaceae Juss.:

This family is represented in Maharashtra by 26 species belonging to 7 genera.

Antigonon leptopus Hook. (S. America), *Cocoloba uvifera* (L.) L. (Tropical America and Atlantic) and *Homalocladium platycladium* (Muell.) Bailey (Solomon Island and New Guinea) are exotic species cultivated as ornamentals and very often seen as escapes near human habitation. A number of species of *Persicaria* (L.) Miller, *Polygonum* Linn. and *Rumex* Linn. are of Asian origin, with the exception of *Persicaria limbata* (Meissn.) Hara and *Rumex vericarius* Linn. which are from Tropical Africa.

Podostemonaceae Rich.:

Five taxa belonging to this family are reported from Maharashtra. However, due to tremendous variability in morphological forms, and fruiting patterns and structures, the exact number of distinct taxa is not estimated properly. Vartak and Bhadbhade (1973) who studied the genus in Maharashtra in detail have described 6 genera, 6 species and 3 varieties. However, the recent FLORA OF MAHARASHTRA by the Botanical Survey of India records only 3 species and 2 varieties of a fourth one, all native to Asia. Both the varieties of *Zeylanidium lichenoides* (Kurz.) Engler, namely *bhorensis* and *khandalensis* are based on material from Khandala and may be ecological varients of one and the same taxon.

Aristolochiaceae Juss.

Among the 10 species of this family recorded from Maharashtra, only 3 are found in the wild, the rest are found as ornamental plants in gardens, most of them being exotics from S. America. Among the 3 wild species of *Aristolochia* Linn., *A. bracteolata* Lamk. is of tropical African origin, while *A. indica* Linn. and *A. tagala* Cham. are widely distributed in India.

Thottea siliquosa (Lamk.) Ding-Hou. is the only member of the other genus, *Bragantea dalzellii* Hk. f., a species considered endemic to Maharashtra being merged with that taxon.

Piperaceae Agardh.

This family consists of 10 species belonging to 2 genera.

Peperomia Ruiz & Pavon: Only *P. pellucida* (L.) Kunth which is S. American in origin and *P. portulacoides* (Lamk.) Dielsm, a native of Mauritius, are found in the wild. A number of exotic species from Brazil are garden plants, among which *Peperomia sandersii* DC. has been so far identified.

Piper L.: Of the 7 Asian species of this genus, *P. gibsonii* DC. and *P. talbotii* DC. were based on material from Bombay Presidency. However, the material of these two species is not present in any local herbaria, and these taxa are known from literature only.

Lauraceae Juss.

This family is represented in Maharashtra by 23 spp. consisting of trees which are distributed in 8 genera (the only twiner *Cassytha filiformis* Linn. earlier placed in this family has been shifted to Family Cassythaceae).

Actinodaphne Nees is represented by an Asiatic species *A. gullavara* (Buch.-Ham.) Almeida (comb. nov.) [Basionym: *Laurus gullavara* Buch.-Ham. ex Nees in Wall. Pl. As. Rar. Ii. 65, 1831], previously known as *A. hookeri* Meissn. *Alseodaphne semecarpifolia* Nees is the only other Asiatic member of the family, sometimes divided into two varieties, but plants are variable in characters and not distinguishable in the field. The third single species genus in Maharashtra is *Beilschmiedia* Nees, represented by the Asiatic species *B. roxburghiana* Nees in Wall. (syn. *Laurus bilocularis* Roxb.). *Cinnamomum* Linn. is the largest genus in Lauraceae, with 8 Asiatic species in Maharashtra.

Litsea Lam. is presently represented by 6 species in Maharashtra; the only endemic taxon is renamed as *Litsea josephii* S.M. Almeida, all earlier names of the species being illegitimate names. Two other species earlier known under genus *Litsea* Lam. have been shifted to a new genus *Neolitsea* (Benth.) Merrill, now named *Neolitsea cassia* (L.) Costerm. (native of Asia and Australia) and *N. floribunda* (Bl.) Almeida (native of Asia).

Out of the 2 spp. of *Persea* Mill., *Persea americana* Mill. is a native of tropical America, rarely cultivated for its fruit. A very old tree of this species existed in the compound of the old Church of Our Lady of Miracles, in Savantwadi and a few plants were seen at MRA Centre at Panchgani, in addition to trees grown at Jijamata Udyan (Victoria Garden), Mumbai. The other wild Asiatic species *Persea macrantha* (Nees) Kostern., has been transferred from genus *Machilus* Nees.

Proteaceae Juss.

This family is represented in Maharashtra by two genera, each with a single species, *Grevillea robusta* A. Cunn. and *Macardonia ternifolia* F. Muell., both hailing from Australia.

Eleagnaceae Juss.

Of the 2 species of this family reported from Maharashtra, *Eleagnus conferata* Roxb. is of Asian origin and occurs in Maharashtra, the other, *E. umbellata* Thunb. (reported as *E. parviflora* Wall. ex Royle from Matheran) is probably a misidentification, as no plant of this species could be located at Matheran, neither is there any specimen in any herbarium.

Loranthaceae Juss.

In Maharashtra, this family is represented by 18 specific and intraspecific taxa belonging to 7 genera (all earlier known under a single genus *Loranthus* Linn. which is now considered monotypic with a single European species). *Dendropthoe* Mart. has 4 species and 2 varieties, all Indian in origin. *Helicanthus* Danser has one species, *H. elasticus* (Desv.) Dans. *Helixanthera* Danser has 3 species and *Scurulla* Linn. has 4 species, *Scurulla gibbosa* (Talbot) Almeida (comb. nov.) [Basionym: *Loranthus gibbosa* Talbot, Trees of Bombay, 2nd Edn: 289, 1902] and *S. stocksii* (Hk. f.) Danser being endemic to Maharashtra. *Macrosolen* Danser has 2 species and *Taxillus* Danser and *Tolypanthes* Van Tigh., one each, all Asiatic in origin.

Santalaceae R. Br.

This family is represented in Maharashtra by three genera, each with a single Asiatic species. *Osyris wightiana* Wall. ex Graham, a species from the Western Ghats, has been confused, by Ramamoorthy in FLORA OF HASSAN DISTRICT, with *O. quadripartita* Salz., a plant of the Holla Range in Sindh, due to misquoting of *O. arborea* Wall. ex DC. under both the species. *Scleropyrum pentandrum* (Dennst.) Mabb. is a rare species only reported by D.G. Dalgado from Savantwadi under *Sphaerocarya wallichiana* W. & A., but subsequently not collected from Maharashtra, although MRA has specimens from Agumbe in South Kanara in Karnataka.

Balanophoraceae Richard & Richard

This family is represented by 2 taxa in Maharashtra, while a third one is of doubtful record. *Balanophora indica* (Arn.) Wall. was recorded by earlier authors like Woodrow (1987) and Cooke (1904). Later, Blatter described a new species from Mahabaleshwar allied to *B. indica* (Arn.) Wall, naming it *B. elkinsii* Blatter, and giving the distinguishing characters between the new taxon and *B. indica* (Arn.) Wall. Cooke had mainly collected his plants from Mahabaleshwar and what he recorded as *B. indica* is probably *B. elkinsii* of Blatter. The question remains — are there two species of *Balanophora* at Mahabaleshwar or only one? Plants are dioecious with tremendous variations. A proper comparison between materials of south Indian *Balanophora indica* (Arn.) Wall. and the Mahabaleshwar material is required to come to a final conclusion. Meanwhile, some authors have listed *B. indica* (Arn.) Wall. as a subspecies under *B. fungosa* Forst. & Forst. f., a European species. Another species *Balanophora abreviata* Bl., a native of Java, was described as a new species under a new genus as *Aeroblastus ambavanense* Reddi at the Botanical Survey of India, Pune. We consider *B. elkinsii* Blatter as endemic to Maharashtra, allied to *B. indica* (Arn.) Wall., and both distinct Asiatic taxa at species rank.

Euphorbiaceae Juss.

This is a one of the largest families in Maharashtra with 167 species and infraspecific taxa belonging to 46 genera. There are 14 Tropical American and 4 Tropical African species:

Tropical American:
Croton bonplandianum Baill.
Euphorbia fulgens Karw.
E. marginata H.B.K.
Hevea brassilensis Muell.-Arg.
Hura crepitans Linn.
Jatropha curcas Linn.
J. gossypifolia Linn.
J. integerrima Jacq.
J. multifida Linn.
J. panduraefolia Anders.
J. podgarica Hk.
Manihot esculenta Cranz.
Manihot glaziovii (L.) Muell.- Arg.
Pedilanthus tithymeloides (L.) Poit.
Tropical African:
Cicca acida (L.) Merrill.
Euphorbia millii Des.
Ricinus communis Linn.
Synadenium grantii Hk. f.

Acalypha Linn. has 12 taxa , probably all of them of Asian origin. *A. rheedii* (Graham) M.R. Almeida comb. nov. is the correct name for *A. paniculata* Miq. [Basionym: *Croton rheedei* Grah., Cat. Bombay Pl. 182, 1839]. *Acalypha gibsonii* (Grah.) Almeida [Basionym: *Croton gibsonii* Graham, ibid.], which is described as allied to *A. rheedii* (Grah.) Almeida by J. Graham, is probably *A. malabarica* Muell.-Arg. which is the only allied *Acalypha* found in localities mentioned by Graham.

Cephalocroton Bedd. and ***Actephila*** Muell.-Arg. have one species each. *Actephila excelsa* (Dalz.) Muell.-Arg. was originally described from Maharashtra but has extended its distribution to Nilgiris in south India.

Agrostistachys Dalz. has two species of which *A. indica* Dalz.,was originally described from Maharashtra but is also distributed in south India. *A. gaudichandii* Hk. f. (Syn. *A. longifolia* Hk. f.) has been reported from Maharashtra but we have not seen reliable specimens of this species from the State. However, the species is quite common in South Kanara in Karnataka.

Andrachne Linn.: The only unnamed species of this genus reported from Marathawada is suspected to be a new species by V.N. Naik (see Naik, 1998), we have tentatively named it after him as *Andrachne naikii* (sp. nov.)

Antidesma Linn.: There are 5 spp. of this genus, all of them native to Asia. We consider *Antidesma pubescens* Roxb. as the correct name for the species going under the name *A. ghassembilla* Gaertn. The proper typification of *A. ghassembilla* Gaertn. is yet to be done. Gaertner in his original publication included part of the protologue which is also included under *Embelia ribes* Burm. f. by N. Burman. It is mentioned that Gaertner described this species on the basis of fruits purchased by him in a Persian market and said to be used for medicinal purposes. It is likely that Gaertner's material is the 'Vidanga' of commerce which is used as an anthelmintic in ayurvedic medicine and is *E. ribes* Burm. f. Therefore *A. ghasembilla* Gaertn. may turn out to be a synonym of *Embelia ribes* Burm. f. The identity of *E. ribes* Burm. f. seems to be correct, although it also has some typification problems, because N. Burman has given a figure of his species with which our Indian materials of *Embelia* match.

Aporosa Baill., *Baliospermum* Blume, *Bischofia* Blume and *Blachia* Benth. have one species each in Maharashtra. Under *Baliospermum* Bl., Suresh (1988) has proposed a new combination *B. solanifolium* (Burm. f.) Suresh. There is a publication titled "Flora Malabarica" by Gmelin, but there is no mention of a "Flora Malabarica" by N. Burman. If there is a reprinted edition of Gmelin's pre-Linnean publication by N. Burman, we are not aware of it. Consequently, Suresh's new combination remains doubtful.

Bridelia Willd.: This genus is represented in Maharashtra by 5 spp., all of them Asiatic in origin. The correct name for the species listed in our Floras as *B. retusa* and renamed as *B. airy-shawi* Li, is *B. spinosa* Willd. Similarly, *Bridelia montana* (Roxb.) Willd. reported by Naik (1998) and Karthikeyan (1993) and *B. hamiltoniana* Wall. ex Hook. [*B. montana* var. *hamiltoniana* (Wall. ex Hook) Haines] perhaps refer to the same taxon.

Libidieropsis collina (Roxb.) Muell.-Arg. should be the correct name for the species currently known as *Cleistanthus collinus* (Roxb.) Benth. This is the plant misidentified as *C. malabaricus* Muell.-Arg. by S.M. Almeida in FLORA OF SAVANTWADI. Therefore, the distribution of *Lebidieropsis collina* (Roxb.) Muell.-Arg. extends from presently known localities in Vidarbha and Marathwada to Danoli in Savantwadi in Konkan. *Cleistanthus malabaricus* Muell.-Arg. is reported from Raigad district by Kothari and Moorthy, which happens to be a new record for Maharashtra. The species is quite common in south India.

Two species of *Codiaeum* Bl. recorded from Maharashtra, with numerous cultivated varieties, are of Asian origin, their home country probably being Java. Three species of *Crozophora* A. Juss. reported from Maharashtra are of Asiatic origin, *C. prostrata* Dalz. originally described from Maharashtra has extended its distribution to south India.

Croton Linn.: This genus has 6 species in Maharashtra, others being shifted to other genera although they were described under *Croton* Linn. and recorded for the State earlier. Except *C. bonplandianus* Baill., which is a native of Tropical America, all the others are Asiatic in origin. *C. gibsonianus* Nimmo ex Graham was originally described from Maharashtra but has now extended its distribution to south India. *Croton virbalae* M.R. Almeida (nom. nov.) is the correct name for *Croton oblongifolius* Roxb., (Fl. Ind. 3: 685, 1832; non Delile, 1814). Balakrishnan had proposed a new name for this species — *C. roxburghii* Balakrishnan. Unfortunately, his name also is a later homonym and therefore illegitimate.

Dimorphocalyx: The correct name for the only species of this genus in Maharashtra is *Dimorphocalyx ramiflorum* (Graham) Almeida (comb. nov.) [Basionym: *Croton ramiflorum* Graham, Cat. Bombay Pl. 182, 1839]. This species is dioecious and it was named *Croton ramiflorus* Graham and also *Croton lawianus* Nimmo ex Graham in Graham's Catalogue. Later Law's material on which the name *Croton lawianus* was based, was placed in a new genus and named *Trigostemon lawianus* Muell.- Arg. The species was transferred to its earlier generic name *Dimophocalyx* Thw. by Hooker (1887) using *T. lawianus* Muell.-Arg. as a basionym, neglecting the two earlier binomials in Graham's Catalogue. Since *Dimophocalyx lawianus* (Muell.-Arg.) Hk. f. is based on the later synonym, a new combination *Dimorphocalyx ramiflorum* (Graham) Almeida (comb. nov.) [Basionym: *Croton ramiflorum* Graham, Cat. Bombay Pl. 182, 1839] is proposed. This species also has an extended distribution to south India.

Drypetes Vahl: This genus has 3 spp. in Maharashtra, all of them of Asian origin. The genus outdates and encompases genera like *Putranjiva* Wall., *Nageia* Roxb., *Palenga* Thw. and *Hemicyclea* W. & A.

Euphorbia L.: The typical genus in the family, it has the largest number of species in Maharashtra, amounting to 43. The genus is heterogenous in nature, comprising fleshy succulent green stemmed perennial plants. A large number of species presently under this genus should actually be grouped under the generic name *Chamaecyce*, on the basis of their being annual herbs. We propose the following new combinations for some of our Indian species which are still under the genus *Euphorbia* Linn. and have to be transferred for better understanding of their status:

Chamaecyce cristata (Roth) Webster
Chamaecyce prostrata (Ait.) Small.
Chamaecyce concanensis (Janarthanan *et* Yadav) Almeida, Dutta & Almeida (comb. nov.) [Basionym: *Euphorbia concanensis* Janarthanan *et* Yadav, Rhodora 5: 148, f. 1, 1995].

In our opinion, the group of underground stemmed perennials without green stem also forms a distinct generic taxon and we recognise it here, with distinct generic status, as *Aemaralmeida* S.M. Almeida & S. Dutta gen. nov. (Type - *Euphorbia fusiformis* Ham. ex Don, Prodr. Nepal p. 62. 1825; DC., Prod. 15(2): 93-94. 1862).

Excocaria Linn.: In Maharashtra it is represented by 4 spp., all of them Asian in origin. *E. agallocha* Linn. is a mangrove plant and *E. cochinchinensis* Lour. is an exotic plant only found in gardens as an ornamental.

Givotia moluccana (Linn.) Sreemadhavan, a Molluccan plant, is an introduced species in Maharashtra and does not occur anywhere in the wild.

Genus *Glochidion* J.R. & G. Forst. is supposed to have 7 Asiatic species in Maharashtra, but the taxa are not very clearly defined. *Hevea brassilensis* Muell-Arg. has come from Amazon in S. America, and *Hippomane mancinella* Linn. from Asia.

Homonoia Lour.: There are 2 spp. of this genus recorded in India. The first author has come across specimens of a third one, *Homonoia intermedia* Haines in the Blatter Herbarium, collected by Rev. Fr. Santapau from Khandala, but it was misidentified and therefore remained unrecorded. Earlier, this species had been described by Haines from Bihar/Orissa. *H. retusa* (Grah.) Muell.-Arg. is described from Maharashtra but extends to south India.

Hura crepitans Linn. is a tropical American tree cultivated in gardens in Mumbai and Nasik.

Jatropha Linn.: It has 8 species in India, 6 of them definitely of American origin. *J. glandulifera* Roxb. is now considered synonymous with *J. glauca* Vahl., another Indian species, and *J. nana* D. & G., originally described from Maharashtra. It will not be surprising if the species considered to be of Indian origin are found to be New World flora in the form of different and priorable binomials as in the case of *Solanum* spp. described from India.

Two species of *Macaranga* Thouars., namely *M. indica* Wt. and *M. peltata* (Roxb.) Muell., are Asiatic in origin. *Mallotus aureopunctata* (Deb.) Muell.-Arg. originally described from Maharashtra has extended its distribution to south India. Monotypic *Margaretea* Linn. f. has originated in Maharashtra. Two species of *Manihot* Mill. with one variety, and one species of *Pedilanthus* with 2 intraspecific taxa, namely *Pedilanthus tithymeloides* ssp. *retusus* (Bth.) Dreg. and *Pedilanthus tithymeloides* var. *nanus* are originally from S. America. *Omalanthus populifolius* Grah. is probably the only species of Euphorbiaceae of European origin found in Maharashtra.

Phyllanthus Linn.: This is another large genus in Maharashtra in Euphorbiaceae, with 14 species distributed in Maharashtra. Some authors unite *Xylophyllum*, *Kirganelia*, *Cicca*, etc. under this genus. However, we consider them distinct. An anti-hepatitis drug is supposed to be derived from species of *Phyllanthus* called "Bhui-awli". However, the correct identity of the true drug plant remains unknown. *P. amarus* Sch., *P. erectus* (Medic.) Almeida, *P. debilis* Klein ex Willd., and *P. tenellus* Roxb. are used with equal efficacy in different parts of the country under the name of *P. niruri*. Linn. — a species only found in the New World at present. *Phyllanthus lawii* Grah. originally described from Maharashtra is also distributed in south India. *P. talbotii* Sedg., described from Karnataka, is grown as a potted plant in Mumbai.

There are two species of *Ricinus* Linn. originally known from Africa.

Sapium R. Br.: There are two species known under this genus — *S. insignis* var. *malabaricum* (Wt.) Hk. f. and *S. sebiferum* (L.) Roxb. We do not quite agree with the placement of *Falcornia insignis* Royle and its variety occurring in Maharashtra, namely var. *malabarica*, in genus *Sapium* R. Br. In fact Muell.-Arg. (1866) disagreed with Graham (1839) regarding the placement of these taxa under *Sapium* R. Br. and had transferred them to *Excoecaria* Linn. which in our opinion also is not the correct generic disposition. We wish to reinstate Royle's generic status for the species and its variety, calling the plant from Maharashtra as *Falconeriia insigne* Royle var. *malabarica* (Hk. f.) Almeida, Almeida & Dutta.

Securinega Comm. ex Juss. in Maharashtra is known by 3 spp., all of them of Asian origin. *Synadenium grantii* Hk. f. is an African species found in Maharastra. Two species of *Tragia* L. and two of *Trewia* Linn. of Asian origin also occur.

Urticaceae Juss. :-

The family Urticaceae Juss. is now segregated into 4 families, namely Urticaceae Juss., Ulmaceae Mirb., Cannabidaceae Endl. and Moraceae Link.

Urticaceae Juss. contains 28 species belonging to 13 genera. All of them are Asian.

Ulmaceae Mirb. contains 6 taxa from 4 genera, all are of Asian origin.

Cannabidaceae Endl. comprises only 1 genus — *Cannabis* Linn. *Cannabis sativa* Linn. is an American species from Mexico but its subspecies *indica* (Lamk.) Small & Crong is Central Asian in distribution.

Moraceae Link is the largest of this group, comprising 73 taxa belonging to 7 genera.

Ficus Linn.: The largest genus of the Family Moraceae is *Ficus* Linn. having 60 taxa in Maharashtra. Most of them are of Asian origin. There are 70 species of *Ficus* Linn. in India. Except for one species each from America, Australia, Africa, Mascaran Island and Pacific and one common to Africa and Australia, all the other taxa are from Asian countries, 2 of them being found in Australia also.

The following taxa of *Ficus* Linn. are distributed beyond Asia:

F. carica Linn. – Africa, Australia (cultivated in India for its edible fruit)
F. hispida Linn. – Asia, Australia
F. virens Dryand. – Asia, Australia
F. tinctoria Forst. f. – Australia (only varieties from Maharashtra)
F. vogellii Miq. – Africa

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[3] Only selected books which are significant to this paper or referred to constantly, have been included in the bibliography. For exhaustive references see Almeida (1996-2001).

Appendix I: Continentwise figures of taxa found in Maharashtra

Native of single continent	No. of taxa
Asia	3,529
America	433
Africa	140
Europe	90
Australia	78
Total	4,270

Native to 2 continents	No. of taxa
Asia & Africa	157
Asia & Australia	90
Asia & America	49
Asia & Europe	42
Africa & Australia	17
America & Australia	9
Europe & Australia	8
Europe & America	7
Europe & Africa	5
America & Africa	4
Total	388

Native to 3 or more continents	No. of taxa
Asia, Africa & Australia	24
Asia, Africa & Europe	21
Asia, Africa & America	9
Asia, America & Australia	4
Africa, Australia & Europe	3
Asia, America & Africa	2
Asia, America & Europe	2
Asia, Australia & Europe	1
Asia, Africa, America & Australia	4
Asia, Africa, America & Europe	2
Asia, Africa, Australia & Europe	1
Total	73

Appendix II: Analysis of numbers of families, genera and species in Maharashtra

Families with highest number of species and intraspecific taxa in Maharashtra

	Family	No. of genera
1.	Poaceae Barnhart	672
2.	Fabaceae Lindley	377
3.	Asteraceae Dumort.	226
4.	Cyperaceae A. Juss.	211
5.	Acanthaceae A. Juss.	204
6.	Orchidaceae A. Juss.	151
7.	Lamiaceae Lindley	100
8.	Scrophulariaceae A. Juss.	96
9.	Asclepiadaceae R. Br.	87
10.	Caesalpiniaceae R. Br.	78

Families with large number of genera in Maharashtra

	Family	No. of genera
1.	Poaceae Barnhart (= Graminae A. Juss.)	158
2.	Asteraceae Dumort. (= Compositae Giseke)	109
3.	Fabaceae Lindley	85
4.	Acanthaceae A. Juss.	58
5.	Rubiaceae A. Juss.	51
6.	Euphorbiaceae A. Juss.	46
7.	Orchidaceae A. Juss.	42
8.	Asclepiadaceae R. Br.	36
9.	Scrophulariaceae A. Juss.	32
10.	Bignoniaceae A. Juss.	32

Families with highest number of endemic genera and species in Maharashtra

	Family	Genera	Species
1.	Fabaceae Lindley	17	34
2.	Acanthaceae A. Juss.	18	31
3.	Poaceae Barnhart	15	25
4.	Asclepiadaceae R.Br.	10	25
5.	Asteraceae Dumort.	11	18
6.	Liliaceae Juss.	6	18
7.	Orchidaceae A. Juss.	9	16
8.	Lamiaceae Lindley	5	12
9.	Euphorbiaceae A. Juss.	7	11
10.	Araceae Juss.	4	10

APPENDIX II: Analysis of numbers of families, genera and species in Maharashtra (*contd.*)

Genera with large number of species and intraspecific taxa in Maharashtra

	Genera	No. of taxa
1.	*Ficus* Linn.	60
2.	*Cyperus* Linn.	58
3.	*Crotalaria* Linn.	48
4.	*Ipomoea* Linn.	44
5.	*Euphorbia* Linn.	43
6.	*Sorghum* Linn.	40
7.	*Indigofera* Linn.	37
8.	*Fimbristylis* Vahl	35
9.	*Acacia* Linn.	34
10.	*Cassia* Linn.	34

Genera with large number of endemic species and intraspecific taxa in Maharashtra

	Genus	No. of endemic species
1.	*Ceropegia* Linn.	15
2.	*Alysicarpus* Neck. ex Desv.	9
3.	*Eriocaulon* Linn.	7
4.	*Habenaria* Willd.	6
5.	*Dipcadi* Medic.	6
6.	*Senecio* Linn.	6
7.	*Neonotis* W. Lewis	5
8.	*Chlorophytum* Ker-Gawl.	5
9.	*Indigofera* Linn.	4
10.	*Crotalaria* Linn.	4

Families represented by exotic species in Maharashtra

	Family	No. of species	Native continent
1.	Asteraceae Dumort.	58	America, Europe, Australia, Africa.
2.	Solanaceae Juss.	53	America, Africa.
3.	Bignoniaceae Juss.	28	America, Africa, Australia.
4.	Arecaceae Sch.	22	America,Africa, Australia, Europe.
5.	Fabaceae Lindl.	19	Australia, America, Europe.
6.	Myrtaceae Juss.	18	Australia, America
7.	Acanthaceae Juss.	18	America.
8.	Verbenaceae Jaume St. Hill	17	America, Australia, Africa.
9.	Apocynaceae Juss.	16	America, Africa.
10.	Passifloraceae Juss.	15	America, Africa.

APPENDIX II: Analysis of numbers of families, genera and species in Maharashtra (*contd.*)

Families in Maharashtra representing 100% exotic species

	Family	Species	Native continent
1.	Bixaceae Link	1	America.
2.	Tropeolaceae DC.	3	America.
3.	Aceraceae Juss.	1	America.
4.	Grossulariaceae DC.	1	Africa.
5.	Vahliaceae (Reichb.) Dandy	1	Africa.
6.	Turneraceae DC.	2	America.
7.	Caricaceae Dum.	1	America.
8.	Cactaceae Juss.	8	America, 1 with Australia.
9.	Martyniaceae Stapf.	1	America.
10.	Phytolaccaceae R. Br.	1	America.
11.	Proteaceae Juss.	2	Australia.
12.	Fagaceae Dum.	1	Europe.
13.	Heliconiaceae (Endl.) Nak.	3	America.
14.	Bromeliaceae Juss.	1	America.

Genera represented by fully exotic species in Maharashtra

	Genera	No. of species	Native continent
1.	*Passiflora* Linn.	15	America, Africa.
2.	*Solanum* Linn.	15	America.
3.	*Eucalyptus* L'Herit.	13	Australia.
4.	*Brassica* Linn.	9	Europe.
5.	*Salvia* Linn.	9	America, Europe.
6.	*Agave* Linn.	9	America.
7.	*Capsicum* Linn	8	America.
8.	*Lantana* Linn.	7	America, 1 common with Australia & Africa, 3 with Africa.
9.	*Nicotiana* Linn.	7	America.
10.	*Alternanthera* Forssk.	6	America.

APPENDIX II: Analysis of numbers of families, genera and species in Maharashtra (*contd.*)

Asian families with largest number of taxa in Maharashtra

	Family	Asian species	Taxa in Maharashtra
1.	Poaceae Barnhart.	672	672
2.	Fabaceae Lindley	268	377
3.	Rubiaceae Juss.	123	135
4.	Asteraceae Dumort.	130	226
5.	Acanthaceae Juss.	166	204
6.	Euphorbiaceae Juss.	128	175
7.	Orchidaceae Juss.	145	151
8.	Asclepiadaceae R. Br.	83	87
9.	Lamiaceae Lindley	78	100
10.	Scrophulariaceae Juss.	76	96

Some prominent American families in Maharashtra

	Family	American genera	Taxa in Maharashtra
1.	Bixaceae Link.	1	1
2.	Papaveraceae A. Juss.	2	2
3.	Erythroxylaceae Kunth.	1	1 (50%)
4.	Tropaeolaceae DC.	1	3
5.	Malpighiaceae A.L. Juss.	4	7
6.	Onagraceae A. Juss.	4	5 (50%)
7.	Turneraceae DC.	1	2
8.	Caricaceae Dumort.	1	1
9.	Cactaceae A. Juss.	8	8
10.	Goodeniaceae R. Br.	1	1 (50%)
11.	Polemoniaceae A. Juss.	1	1
12.	Solanaceae A. Juss.	15	54
13.	Passifloraceae Juss. ex Kunth.	1	14
14.	Bignoniaceae Juss.	15	23
15.	Nyctaginaceae Juss.	3	4
16.	Phytolaccaceae R. Br.	1	1
17.	Heliconiaceae Nakai	1	3
18.	Agavaceae Endl.	3	10

Prominent African families in Maharashtra

	Family	African genera	Taxa in Maharashtra
1.	Geraniaceae Juss.	2	7
2.	Grossulariaceae DC.	1	1
3.	Aizoaceae Rudolphi.	3	3

APPENDIX II: Analysis of numbers of families, genera and species in Maharashtra (*contd.*)

Prominent European families in Maharashtra

	Family	European genera	Taxa in Maharashtra
1.	Rosaceae Juss.	5	7
2.	Caryophyllaceae Juss.	7	10
3.	Brassicaceae Burnett.	10	15

Prominent Australian families in Maharashtra

	Family	Australian genera	Taxa in Maharashtra
1.	Myrtaceae Juss.	3	41
2.	Datiscaceae Lindley	1	1
3.	Leeaceae Dumort.	1	1

Monogeneric families in Maharashtra.

	Family	Native continent
1.	Nelumbonaceae Dumort.	E. Asia & E. North America.
2.	Pittosporaceae R. Br.	South Africa to New Zealand & Pacific.
3.	Ancistrocladacaeae Walp.	Old World Tropics.
4.	Moringaceae Dumort.	Semi-arid Africa & Asia.
5.	Punicaceae Horan	Europe.
6.	Trapaceae Dumort.	Old World, except Pacific.
7.	Alangiaceae DC.	Old World Tropics.
8.	Symplocaceae Desf.	Tropical America & Old World.
9.	Sphenocleaceae DC.	Tropics.
10.	Ceratophyllaceae Gray	Cosmopolitan.
11.	Typhaceae Juss.	Cosmopolitan.
12.	Costaceae Nakai	Nepal.
13.	Cannaceae Juss.	Tropical & Warm America.
14.	Heliconiaceae Nakai	Tropical America, S.W. Pacific.
15.	Taccaceae Dumort	Tropics.
16.	Ruscaceae Hutch.	Europe, Mediterranean to Iran.
17.	Typhaceae Juss.	Cosmopolitan.
18.	Najadaceae Juss.	Cosmopolitan.

APPENDIX II: Analysis of numbers of families, genera and species in Maharashtra (*contd.*)

Monotypic genera in Maharashtra (According to Santapau and Henry 1999)

Adenoon Dalz.
Adhatoda Miller
Amherstia Wall.
Anamirta Colebr.
Ananas Mill.
Apium Linn.*
Apluda Nees*
Belacamanda Adans.*
Benincasa Savi
Bignonia Linn.*
Bischofia Bl.
Caesulia Roxb.
Calacanthus T. Anders. ex Benth.
Calycopteris Lamk.
Cannabis Linn.
Carvia Bremek.
Castanospermum A. Cunn.
Castellia Cerv.
Catha Forsk. ex Scop.
Chloroxylon DC.
Chukrasia A. Juss.*
Cicca Linn.
Cocos Linn.
Colebrookea Smith
Colvillea Boj. ex Hk.
Cottonia Wt.
Danthonidium C.E. Hubb.
Dicoelospermum Clarke
Digera Forsk. *
Dinebra Jacq.
Erinocarpus Nimmo ex J. Grah.
Goniogyne DC.
Griffithella (Tul.) Warm
Helicanthus Danser *
Hemidesmus R. Br.
Hydrilla Rich.
Hygroryza Nees
Indopoa Bor
Kigelia DC. *
Kleinhovia Linn.
Lawsonia Linn.
Limonia Linn.
Martynia Linn.
Microcarpaea R. Br.
Millingtonia L. f.
Moullava Adanson
Nechamandra Planch.
Nelsonia R. Br.
Nicandra Adans.
Nogra (Baker) Merrill
Nothosaerva Wt.
Nyctanthes Linn.
Ophrestia (Dalz.)
Ougenia Benth.
Pedalium Linn.
Pentapetes Linn.
Pistia Linn.
Polyzygus Dalz.
Pongamia Vent.
Pseudodichanthium Bor
Pseudodanthonia Bor & C.E. Hubb.
Ravenala Adans. *
Rhoeo Hance
Ricinus Linn. *
Schleichera Willd.
Solena Lour.
Sphenoclea Gaertn.
Tamarindus Linn. *
Tetrapanax Koch.
Thelepaepale Bremek.
Thelepogon Roth. ex R. & S.
Thysanolaena Nees
Toddalia Juss.
Triplopogon Bor
Urochondra C.E. Hubb.
Wagatea Dalz.
Willisia Warm.
Zanichellia Linn.
Zanonia Linn.
Zea Linn.

* Probably monotypic

Some prominent American genera in Maharashtra

Acer Linn.
Allamanda Linn.
Anacardium Linn.
Annona Linn.
Arachis Linn.
Araujia Brot.
Argemone Linn.
Bixa Linn.
Brya P. Browne
Bursera Jacq. ex Linn.
Choisya Kunth
Clusia Linn.
Dioclea Kunth
Galphimia Cav.
Gliricidia Kunth
Guaiacum Linn.
Guazuma Miller
Hyoscyamus Linn.
Iochroma Benth.
Luehea Willd.
Malachra Linn.
Malpighia Linn.
Malvaviscus Adanson
Muntingia Linn.
Nicandra Adans.
Pachira Aubl.
Petunia A. Juss.
Phlox Linn.
Plumeria Linn.
Pseudobombax Dugand.
Quassia Linn.
Ravenia Vell.
Rheedia Linn.
Schinus Linn.
Solandra Linn.
Solenopsis C. Presl.
Stemmadenia Benth.
Stigmaphyllum A. Juss.
Swietenia Jacq.
Theobroma Linn.
Thevetia Linn.
Tropaeolum Linn.
Turbina Raf.
Ximenia Linn.

Appendix II: Analysis of numbers of families, genera and species in Maharashtra (*contd.*)

Some prominent African genera found in Maharashtra

Acokanthera G. Don
Adansonia Linn.
Azima L
Blighia Koenig
Brexia Noronha ex Thouars.
Ceratonia Linn.
Colvillea Bojer.
Dichrostachys (DC.) Wt. & Arn.
Dicoma Cass.
Dombeya Cav.
Eruca Miller
Felicia Cass.
Hurenia R. Br.
Lagenaria Seringe
Lycium Linn.
Mesembryanthemum Linn.
Mundulea (DC.) Benth.
Myrtus Linn.
Ochna Linn.
Pelargonium L'Herit.
Roupellina (Baillon) Pichon
Sclerocarpus Jacq.
Stapelia Linn.
Stapelianthus Choux ex White & Sloane
Tamarindus Linn.
Trachylobium Heyne
Vahlia Thunb.
Viola Linn.

Some prominent European genera in Maharashtra

Achillea Linn.
Aster Linn.
Bidens Linn.
Bryonia Linn.
Calendula Linn.
Capsella Medikus
Centaurea Linn.
Cerastium Linn.
Christia Moench.
Cicer Linn.
Cichorium Linn.
Cirsium Miller
Coriandrum Linn.
Couroupita Aublet
Cynara Linn.
Daucus Linn.
Echium Linn.
Foeniculum Miller
Fragaria Linn.
Iberis Linn.
Myosotis Linn.
Pistacia Linn.
Potentilla Linn.
Ruta Linn.
Scorzonera Linn.
Sedum Linn.
Silene Linn.
Sinapis Linn.
Stellaria Linn.
Trapopogon Linn.
Trifolium Linn.
Vinca Linn.

Introduced exotic weeds in Maharashtra

	Species	Native continent
1.	*Argemone mexicana* Linn.	America
2.	*Mikania amara* Willd.	America, Australia
3.	*Parthenium hysterophorus* Linn.	America
4.	*Synedrella nodiflora* (Linn.) Gaertn.	America
5.	*S. vialis* Gray	America
6.	*Tridax procumbens* Linn.	America
7.	*Scoparia dulcis* Linn.	America
8.	*Martynia annua* Linn.	America
9.	*Ruellia baikikei* Woodrow	America
10.	*Lantana camara* Linn.	America
11.	*L. camara* var. *hybrida* Mold.	America
12.	*L. camara* var. *mista* Bailey	America
13.	*L. camara* var. *nivea* Bailey	America
14.	*L. montenidensis* Brig.	America
15.	*L. salvifolia* Jacq.	America
16.	*L. urticifolia* Mill.	America
17.	*Alternanthera paronychiodes* St. Hill.	America
18.	*A. tenellus* Colla var. *bettzikiana* Valdk.	America
19.	*A. pungens* H.B.K.	America
20.	*A. sessilis* (Linn.) R. Br.	America
21.	*A. tenella* Colla	America
22.	*A. polygonoides* var. *erecta* Mart.	America
23.	*Lemna gibba* Linn.	Australia
24.	*L. perpusilla* Torran.	America
25.	*Ruellia brittoniana* Leonard	America
26.	*R. tuberosa* Linn.	America
27.	*Acanthospermum hispidum* DC.	America
28.	*Aeschynomene americana* Linn.	America
29.	*Ageratina adenophora* (Spreng.) King & Robins.	America
30.	*Amaranthus dubius* Mart. & Thell.	Reg. Trop.
31.	*Boerhavia erecta* Linn.	America
32.	*Cuscuta australis* R. Br.	Europe
33.	*Cuscuta campestris* Decne & Engler	Europe
34.	*Desmodium neomexicanum* A. Gray	America
35.	*Desmodium scorpourus* (Sw.) Desv.	America

Appendix II: Analysis of numbers of families, genera and species in Maharashtra (*contd.*)

Introduced exotic weeds in Maharashtra (*contd.*)

Species	Native continent
36. *Eichhornia crassipes* (Mart.) Solms.	America
37. *Gomphrena celosoides* Mart.	America
38. *Melochia pyramidata* Linn.	America
39. *Oxalis deepei* Lodd.	America
40. *Schouwia purpurea* (Forsk.) Sch.	Arabia
41. *Solanum eleagnum* Cav.	America
42. *Solanum hovei* Dunal.	America
43. *Synedrela vialis* (Less.) A. Gray	America
44. *Xanthium pungens* Wallroth.	Cosmopolitan

Spices & condiments introduced in Maharastra

Species	Native continent
1. *Coriandrum sativum* Linn.	Europe
2. *Apium graveolens* Linn.	Europe
3. *Foeniculum vulgare* Miller	Europe
4. *Peucedanum satiosum* Benth.	Europe, Africa
6. *Cuminum cyminum* Linn.	Australia, Europe
7. *Brassica* Linn. (various spp.)	Europe

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ON THE DATES OF PUBLICATION OF THE *JOURNAL OF THE BOMBAY NATURAL HISTORY SOCIETY*, VOLUMES 1-100 (1886-2003), AND OTHER MATTERS

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Key words: Bibliography, Bombay Natural History Society, Indian subcontinent

The objectives of this paper are: 1) to put on record in one place the known dates of issues of the *Journal of the Bombay Natural History Society* since its commencement, and 2) to draw attention to the importance of dating every issue. The date of publication is essential in implementing the Law of Priority established by the International Code of Zoological Nomenclature, as the *Journal* carries descriptions of new taxa. In the process, the pagination of each part of the *Journal* is also presented.

INTRODUCTION

Some certainty as regards the correct date of publication of scientific material, especially of those that contain original descriptions of new taxa, is essential in implementing the Law of Priority. This law is to be found in the International Code of Zoological Nomenclature (ICZN 1999). One reason for the Code is to promote stability in scientific nomenclature.

"Whenever two names belonging to the same taxon are discovered, the problem of the validity of one is decided by the *Law of Priority*. It means the valid name of a taxon is the oldest (taken from the date first published) available name..." (Kapoor 1998). In the early 19th century, when ornithologists were describing avifaunas of various regions for the first time, there were innumerable instances when different names were proposed for the same taxon. Sometimes, in that period, a description was published in more than one journal! If it contained new taxa, dating each of the publications was critical (Brooks 1871, 1872). Without this simple law, there would be utter chaos in choosing and fixing a name for a taxon.

The *Journal of the Bombay Natural History Society* (*JBNHS*) is the foremost journal of its nature in the Oriental Region. It is the "symbol of the Society, it was what members joined for. No one would join the Society if it were not for the journal", (Anon. 1933, p. 81). One hundred volumes published over 118 years make it an invaluable repository of natural history literature. The results of important regional faunal surveys are published in its pages. Many new taxa of various phyla have been described in the *JBNHS*. Certainty as to the dates of publication of each of these is highly desirable.

Editors may now not be as punctilious as taxonomists about the actual date of publication of their journal. Often, in a journal of long standing, like the *JBNHS*, editors change, partly to bring to the editing, skills and knowledge that are necessary to cope with the evolving nature of the subject. What editor thirty years ago knew anything of molecular studies? With these changes come changes in editorial policy, some deliberate, others accidental. In the context of accidental change lies the potential for dates of publication to be neglected, especially as it is probably now harder than it was to keep a printer to a strict timetable that allows a guarantee that the stated date of publication is actually the date distribution commenced. Ideally the date of each issue of a journal should be a matter of record.

A secondary issue is volume composition. Many are the authors who take the dates for papers they have looked up from the spine of the

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bound volume. Yet, if three parts of a journal's volume are supposed to be printed in one calendar year (say 1900) and, due to circumstances beyond anyone's control, the third part is actually printed in the following year (1901), it might retain a year on its cover (volume year), usually the previous year (1900) when it was actually supposed to have been printed, and not the actual years of printing (1900/01)! To both the taxonomist and the bibliographer, the latter date (1901), on which the last part was actually printed, is vital. In such a situation scientists know, or should know, that the citation they give for a paper should have the year of actual printing after the author's name and the volume year, in parentheses at the end of the citation, thus:

> Abdulali, Humayun (1967): More new races of birds from the Andaman and Nicobar Islands. *J. Bombay nat. Hist. Soc. 63(2)*: 420-422 (1966).

Today there are few new taxa being described of mammals and birds. But there are new descriptions of reptiles, spiders, insects, etc., in almost every part of the *JBNHS*. The Law of Priority applies to these in equal measure, e.g. the following paper from Vol. 72 was published in a Part (3) with a volume year 'December 1975', but the actual date of publication was 13.viii.1976.

> Biswas, S. (1976): Reptilia from Bhutan with description of a new species of *Calotes* Rafinesque. *J. Bombay nat. Hist. Soc. 72(3)*: 774-777 (1975).

A separate Code covers the realm of botany, but the Law of Priority is just as relevant to plants!

METHODS

To establish the dates of publication of the parts of the *JBNHS*, I looked at each part individually and located a date of publication on it. In a majority of cases, this was pretty straightforward. Such a date was published either on the cover, in a colophon (at the bottom of the last page of each part), or at the top of the Contents page. In some instances only a year was printed, or a month and a year, and in some, not even that. Mercifully, dates of publication were also printed on the 'title-page' that was inserted in the 5th or 'Index' part of a volume.

The ideal scenario would have been to examine a complete set that had the covers of all the parts intact. This was not possible as, over the years, libraries have bound parts in their volumes and, in the process, discarded their covers. It may be worth noting, however, that major zoology libraries, like that of the Natural History Museum in London, have for many years been making sure that covers are always bound in.

However, I could not trace a single library source for a complete 'master' set of the *Journal* — consisting of all of its parts (including the Index) along with their covers and insert-slips. Even the Society's library does not have one! Research was thus carried out at the Osmania University College of Science Library, Hyderabad, in the library of the late Humayun Abdulali, in Mumbai, and in the premises of the Bombay Natural History Society, where there were at least 4 incomplete sets (in the sense mentioned above). Help was also obtained from the Ornithology & Rothschild Libraries at the Natural History Museum in Tring, England.

Duncan (1937), in his quest to establish the correct date of publication of the *Proceedings of the Zoological Society of London*, had dug out the ledgers and day-books of yore, not just from the offices of the Zoological Society of London, but also from those of its printers, Messrs. Taylor and Francis! Sadly, such meticulous records, even if kept during past years, have not been retained at the Bombay Natural History Society's office.

RESULTS

The researched data have been tabulated (Table I) under the following column heads:

Year: This is the volume year that is published on the cover of a journal and pertains to the calendar year during which all the parts that comprised a volume were to be published. It should be noted that many early journals, e.g. *The Proceedings of the Zoological Society of London*, were published for what we now call a financial year, and that only some of such organisations suggested that the bound volume be marked with a date such as 1900/01. The *JBNHS*, when it departed from the calendar year, was not alone in so doing. Vols I-VII had volume years printed on their covers and all the parts were in fact published within their respective calendar years (except perhaps Part 4 of Vol. VI which was published after 31.xii.1891). Delays in publication began with Part 3 of Vol. VII, which was published on 15.i.1893, instead of in 1892, though the volume carried 1892 on its cover as the volume year. Part 4 was published on 23.iv.1893 and did not carry a volume year on its cover. From then on, until Vol. XXXIX, the volume year was not published on the cover of the *JBNHS*. From Vol. XL onwards, a month and a year were published on the covers of the parts of the *JBNHS*.

Volume: This column contains the volume number. Volume numbers 'I-XLIV' were printed in Roman numerals, which were changed to Arabic from Vol. 45 onwards. The process that was followed by the Society in dating the *JBNHS* has resulted, at least in some libraries, in several bound volumes carrying two years on their spines; but in such cases all copies should be bound to show this and the Society should say so in the last part of a volume.

Part: Vols I-54 contained 4 parts each. A 5th part, with a title page, contents of the volume, alphabetical list of contributors, list of plates, index to illustrations, list of office-bearers, list of members, accounts and, index, was published along with the Vols I-XXVII. This 5th part was split into 2 sections from Vol. XXVIII-51, with the first section containing the above information only from parts 1 and 2 of a volume and the second that from parts 3 and 4. From Vol. 52-71, a single index was published for each volume (see Table 1 for further details). From Vol. 55, three parts were issued per volume, which was supposed to be published in one calendar year.

Pages: The Contents were sometimes paginated with lowercase Roman numerals and sometimes not at all. I have ignored both of these. If the last printed page of a part ended on an odd page number (*recto*) and the page behind it (*verso*) was a blank, e.g. Vol. XXXIII (2): 222-471, the pagination of the following part, which always began with an odd numbered page, would commence after leaving out a page number (which was the notional number of the *verso* of the previous part), e.g. Vol. XXXIII (3): 473-744. If the part ended with an even page number (*verso*), as in the last example, the first page of the following part followed serially, XXXIII (4): 745-1005. The 5th or Index parts were always paginated with lowercase Roman numerals.

Date of publication: This is the date on which a part of a volume was actually published. There are instances where such a date comprised of a month and a year or just a year. For the period 1997-2001, the date of publication given on the Contents page was apparently arbitrarily fixed as the 1st day of April, August and December respectively for the three parts of a volume. This was irrespective of the actual date of publication, and an invidious practice, as it could well lead to newly proposed taxa being unable to prove their priority. However, from Part 2 of Vol. 99, this anomaly was rectified and the actual date of publication included in the colophon.

Notes: This column contains random bits and pieces of information about the *JBNHS*, which I thought would be of interest to the reader. The editors of the *JBNHS* generally used insert-slips to convey last minute information like errata, apologies for late publication, notices on policy matters regarding publications, etc. In this paper I have quoted those insert-slips that affected the bibliographical aspects of the *JBNHS*. Though a history of the *JBNHS* is not the subject of this paper, this column tries to illuminate facets from its years of existence that show brief glimpses of its 'life'—the travails of wars, the problems of labour at the press, the pressure of deadlines and the pride of supplements that mark its milestones.

It is now perhaps only of historical interest as to which parts of volumes of the *JBNHS* the Society mailed to its members in respect of each subscription year. In most cases, the 4 (or later, 3) mandatory parts may have been from at least two volumes! Whether the Society promised a *volume* comprising of 4 parts of the *JBNHS*, to its subscribing members, or simply any 4 parts of the *JBNHS* for their annual subscription, is another moot point.

Two Appendices are given at the end of this paper. One contains a list of the General Indices of subjects and authors (Appendix I). The other (Appendix II) is a chronological list of the editors of the *JBNHS*. This is an up-to-date list, following the one compiled by Anon. (1987). Admirable accounts of the *JBNHS* and its role in the study and documentation of Indian natural history have been published in earlier volumes (Anon. 1952, Ali 1987).

On indices

The Bombay Natural History Society had a fine tradition of producing indices for each volume of the *JBNHS*. This lasted from Vol. VII-71 (1892-1974) without a break even though some of these indices were prepared several years after the volumes were published (e.g. Vols. 54, 55, 56, 57). Subsequently, indices were created for just 3 further volumes (79, 80, 82). The Society also produced 8 comprehensive indices entitled "General Index of Subjects and Authors," covering variously consolidated Volumes from I-63 (Appendix I). The amount of information that the early index volumes contained was pared down in later years, with lists of office-bearers, accounts and minutes of annual general body meetings being relegated to the 3rd part of a volume and the lists of members being entirely omitted.

Old-timers still rue the day the Society began slipping up on producing indices to the *JBNHS*. The usefulness of Indices cannot be emphasised enough. Suffice it to say that they make available, instantaneously, what could otherwise become a "wild goose chase!" Worldwide, indices have regrettably taken a back seat. Many editors of renowned journals do not even try to create one. However, with publication 'online' nowadays, search engines will make such indices much less important, so that the wish for a good old index is probably unrealistic. In spite of this, there are several important journals, like the *JBNHS*, in circulation today, that have not yet crossed the technological barriers involved in migrating towards 'online' publication. However, I daresay, that with wordprocessors and desktop publishing, indexing should now become easier for them. Perhaps a simple leap of faith is required in that direction, by the Board of Editors, at the commencement of this *Journal*'s new century!

Conclusion

In all, the Bombay Natural History Society published 355 parts of the *Journal* (1886-2003), in the publication's first hundred years. Vols I-54 had 4 parts each, except one issue of combined parts [Vol. 52 (2&3)], i.e. 215 parts totally. Vols 55-100 had 3 parts each, except 1 issue of combined parts [Vol. 100 (2&3)], i.e. 137 parts totally. In addition to this, 3 supplements were issued, taking total to 140 parts.

Over the years, the various printers of the *Journal* have been (in alphabetical order): Caxton Printing Works; Diosecan Press, Madras; Education Society's Press, Byculla; Leader's Press Pvt. Ltd.; St. Francis Industrial Training Institute, Borivli, Bombay; Times of India Steam Press, Bombay; Times Press, Bombay.

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society*

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
1886.	I.	1.	1-30.	i.1886.	Contents on front cover. In Part 1 there was a "Notice: Under a resolution passed at the General Meeting of the 7th September 1885, this first number of the Journal is issued *gratis*, after which it will be optional to Members to subscribe it at the rate of Rupees Five per annum." Part 4 had an insert-slip from R.A. Sterndale, Editor, entitled "Editor's Apology." It read as follows, "I feel that I owe our members some apology for the great delay in issuing this number of the journal. It is due in great measure to my having been hindered by repeated attacks of fever, and also to some difficulty in preparing the illustrations. The tinting by hand of one thousand plates has been the laborious work of my leisure hours for some days; but I hope that in future, when the journal will have more funds to its credit, such coloured plates will be executed in England by a well-kuown (*sic*) firm."
		2.	29-90.	iv.1886.	
		3.	91-151.	vii.1886.	
		4.	153-243.	x.1886.	
1887.	II.	1.	1-71.	i.1887.	Part 1: "With rules and list of members." Part 2: Published after 26.iv.1887. Miscellaneous Note of that date was published on p. 140.
		2.	73-158.	iv.1887.	
		3.	159-219.	vii.1887.	
		4.	221-291.	x.1887.	
1888.	III.	1.	1-68.	i.1888.	Part 1 had "1886" *in errore* on p. 1. Part 2: Published after 28.iv.1888. Letter of that date was published on p. 138. Part 3: Published after 2.vii.1888. Proceedings of that date were published on p. 199. Part 4: Published after 11.xii.1888. Proceedings of that date were published on p. 268.
		2.	69-141.	iv.1888.	
		3.	143-203.	vii.1888.	
		4.	205-269.	xii.1888.	
1889.	IV.	1.	1-82.	i.1889.	Part 1: Published after 23.iii.1889. Miscellaneous Note of that date was published on p. 71. Part 3: Published after 7.ix.1889. Miscellaneous Note of that date was published on p. 230.
		2.	83-162.	1889.	
		3.	163-235.	1889.	
		4.	237-321.	1889.	
1890.	V.	1.	1-96.	1890.	Parts from this volume are numbered in Arabic numerals. Part 1: Published after 6.ii.1890. Proceedings of that date were published in it. Part 2: Published after 26.v.1890. Miscellaneous Note of that date was published on p. 190. Part 3: Published after 27.viii.1890. Miscellaneous Note of that date was published on p. 309. Part 4: Published after ?.xii.1890 [maybe in 1891?]. Miscellaneous Note of that date was published on p. 423. This Part was reprinted in 1891.
		2.	97-197.	1890.	
		3.	199-313.	1890.	
		4.	315-426.	1890.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
1891.	VI.	1.	1-127.	1891.	Part 1: Published after iv.1891. Miscellaneous Note of that date was published on p. 118. Part 2: Published after 1.vii.1891. Proceedings of that date were published on p. 278. Part 3: Published after 6.xi.1891. Miscellaneous Note of that date was published on p. 424. Part 4: Published after 31.xii.1891. Miscellaneous Note of that date was published on p. 504. An insert-slip "Notice" in this Part states, "An index to this volume is in course of preparation, and will be published in the next number." An incomplete Index in the Osmania University College of Science Library has pp. i-xviii.
		2.	129-283.	1891.	
		3.	285-428.	1891.	
		4.	429-509.	1891.	
		[5.]	i-?	?	
1892.	VII.	1	1-124.	1.vi.1892.	Part 4 onwards there is no volume year printed on the cover. A "Notice" in the Index (Part 5) reads, "The delay in the publication of this Number was due to the non-arrival of the Plates from England, but the Editor hopes that the notice inserted in No. IV. will have prevented Members from binding Vol. VII. prematurely. The Index, &c., will in future always be issued in this manner as a separate Number (Part V.)."
1892.		2.	125-262.	1.x.1892.	
1892.		3.	263-412.	15.i.1893.	
		4.	413-561	23.iv.1893.	
		5.	i-xxi.	1.viii.1893.	
—	VIII.	1.	1-161.	1.vii.1893.	
		2.	162-330.	15.x.1893.	
		3.	331-452.	1.ii.1894.	
		4.	453-570.	23.iv.1894.	
		5.	i-lviii.	15.ix.1894.	
—	IX.	1.	1-110.	1.ix.1894.	
		2.	111-234.	1.xii.1894.	
		3.	235-344.	20.iii.1895.	
		4.	345-509.	20.vi.1895.	
		5.	i-lviii.	15.x.1895.	
—	X.	1.	1-160.	10.xi.1895.	
		2.	161-338.	24.iii.1896.	
		3.	339-538.	30.viii.1896.	
		4.	539-702.	12.i.1897.	
		5.	i-lxvii.	12.vi.1897.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
—	XI.	1.	1-170.	10.vi.1897.	
		2.	171-346.	1.xi.1897.	
		3.	347-554.	28.ii.1898.	
		4.	555-750.	12.vii.1898.	
		5.	i-xxxiv.	1.xii.1898.	
—	XII.	1.	1-234.	10.xii.1898.	
		2.	235-436.	30.iii.1899.	
		3.	437-592.	7.vii.1899.	
		4.	593-794.	8.xi.1899.	
		5.	i-xliii.	31.iii.1900.	
—	XIII.	1.	1-198.	15.iv.1900.	Part 5 contained: “General Index of Subjects and Authors for Vols. I to XIII Inclusive,” pp. xxix-lxvi.
		2.	199-398.	29.vii.1900.	
		3.	399-562.	20.i.1901.	
		4.	563-721.	18.v.1901.	
		5.	i-xcvii.	6.x.1901.	
—	XIV.	1.	1-196.	24.i.1902.	
		2.	197-408.	24.v.1902.	
		3.	409-637.	18.x.1902.	
		4.	639-828.	10.ii.1903.	
		5.	i-lxxvi +1.	30.v.1903.	
—	XV.	1.	1-161.	10.vi.1903.	
		2.	162-374.	28.x.1903.	
		3.	375-536.	15.ii.1904.	
		4.	537-735.	27.vi.1904.	
		5.	i-lxxix.	16.x.1904.	
—	XVI.	1.	1-191.	17.xii.1904.	
		2.	192-398.	15.iv.1905.	
		3.	399-531.	5.viii.1905.	
		4.	532-763.	2.xi.1905.	
		5.	i-lxxxiv.	31.i.1906.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
—	XVII.	1.	1-258.	23.iv.1906.	Part 5 contained: "General Index of Subjects and Authors for Vols. XIV to XVII Inclusive," pp. xli-lxiv.
		2.	259-554.	20.ix.1906.	
		3.	555-856.	15.ii.1907.	
		4.	857-1045.	20.vi.1907.	
		5.	i-cxxiv.	17.xii.1907.	
—	XVIII.	1.	1-225.	12.xi.1907.	Part 5 contained: "Catalogue of books in the Bombay Natural History Society's Library, March 1908, compiled by B.D. Richards, B.Sc., Honorary Librarian," pp. xli-lxx.
		2.	226-524.	13.iv.1908.	
		3.	525-709.	15.vii.1908.	
		4.	710-945.	15.xi.1908.	
		5.	i-cxxii.	31.xii.1908.	
—	XIX.	1.	1-285.	15.iv.1909.	In the Proceedings of the Society dated 18.iii.1909 (p. 547), "the Secretary announced that the Index Number (No. 5, Vol. XVIII) of the Society's journal had just been published and as No. 1, Vol. XIX., would be ready in a few weeks the two numbers would be posted together to up-country members." Part 5 contained: "A Supplementary Catalogue of Books in the Society's Library. May 1910" by Hon. Librarian (pp. lxvii-xciv) and an Appendix: Anon. "A list of the publications relating to the Oriental Region from the 'Zoological Record,' 1907 (pp. xcv-cxx).
		2.	287-554.	15.viii.1909.	
		3.	555-774.	15.xi.1909.	
		4.	775-1021.	28.ii.1910.	
		5.	i-clxvi.	24.vi.1910.	
—	XX.	1.	1-257.	13.vi.1910.	Part 5 contained: Blatter, E. (1911): 'A bibliography of the Botany of British India and Ceylon,' (pp. lxxix-clxxxv), and, 'Anon. (1911): A list of the publications relating to the Oriental Region,' from the "Zoological Record," 1908, (pp. clxxxvi-ccxvii).
		2.	259-545.	12.x.1910.	
		3.	547-899.	31.i.1911.	
		4.	901-1185.	20.v.1911.	
		5.	i-cclx.	30.x.1911.	
—	XXI.	1.	1-302.	31.x.1911.	Part 5 contained: "Mimicry in silk-worm moths" (with 3 plates) by J.M. Fawcett (pp. lxxxix-xci).
		2.	303-719.	31.iii.1912.	
		3.	721-1107.	30.vii.1912.	
		4.	1109-1364.	20.xi.1912.	
		5.	i-clxxiii.	21.iv.1913.	
—	XXII.	1.	1-218.	21.iv.1913.	The back cover of Part 1 had a Notice with a list of old issues of the *Journal* for sale. This stated that the following Numbers were reprinted, "with no plates": I: 1,2,3; II: 4; III: 1,2,3,4; IV: 1,2,4; V: 2,4; VI: 3,4; VII:1,3; X: 2,4; XV: 3; XVI: 2,3,4; XIX: 4.
		2.	219-418.	30.ix.1913.	
		3.	419-652.	20.xii.1913.	
		4.	653-823.	31.iii.1914.	
		5.	i-cxxxiv.	10.vii.1914.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
—	XXIII.	1.	1-181.	30.vi.1914.	
		2.	183-384.	20.xi.1914.	
		3.	385-592.	2.ii.1915.	
		4.	593-802.	25.v.1915.	
		5.	i-cxx.	30.ix.1915.	
—	XXIV.	1.	1-199.	30.ix.1915.	Part 4 had contents on the inside front cover. Also an insert-slip facing frontispiece, stating, "The recent Paper Control (Economy) Order of the Government of India compels the Society to limit its Journal to an issue of 120 pages inclusive of illustrations, cover and index. We express our regrets to members and to contributors, publication of whose articles is necessarily delayed." New articles started from the middle of pages where the earlier ones ended. Part 5 contained: "General Index of Subjects and Authors for Vols. XVIII to XXIV Inclusive," with separate pagination 1-79.
		2.	201-386.	31.i.1916.	
		3.	387-621.	20.vi.1916.	
		4.	623-852.	25.x.1916.	
		5.	i-cxxxvi, 1-79.	15.vi.1917.	
—	XXV.	1.	1-160.	20.iii.1917.	Part 1 had an insert-slip "Notice" from the Editors: "The Index number of Vol. XXIV has been delayed owing to the manuscript of the index not having arrived from England. It will be published and issued to members as soon as possible and will also include a General Index of Volumes XVIII to XXIV, inclusive. The previous General Indexes (*sic*) were published as follows:- Vols I to XIII, in No. 5, Vol. XIII. Vols XIV to XVII, in No. 5, XVII." March 1917.
		2.	161-324.	15.ix.1917.	
		3.	325-520.	15.i.1918.	
		4.	521-770.	10.vi.1918.	
		5.	i-cxi.	28.xii.1918.	
—	XXVI.	1.	1-318.	20.xii.1918.	
		2.	319-704.	30.v.1919.	
		3.	705-884.	20.x.1919.	
		4.	885-1055.	31.i.1920.	
		5.	i-cxxxi.	15.i.1921.	
—	XXVII.	1.	1-192.	1.vii.1920.	
		2.	193-415.	20.xii.1920.	
		3.	416-650.	31.iii.1921.	
		4.	651-973.	31.vii.1921.	
		5.	i-cxlvi.	25.ii.1922.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
—	XXVIII.	1.	1-304.	30.xii.1921*.	*Mengel (1972).
		2.	305-570.	25.iii.1922*.	
		3.	571-821.	30.vi.1922.	
		4.	823-1150.	20.xii.1922.	
		5. I (1&2).	i-liv.	1923.	
		5. II (3&4).	i-xlix.	1923.	
—	XXIX.	1.	1-308.	20.iv.1923.	
		2.	309-576.	25.viii.1923.	
		3.	577-847.	31.xii.1923.	
		4.	849-1070.	15.v.1924.	
		5 (1&2).	i-li.	1924.	
		5 (3&4).	i-xlii.	1924.	
—	XXX.	1.	1-234.	1.x.1924.	Contents page of Part 2 *in errore* regarding 1st page, "236". It is 235 in text. 2 indices were published.
		2.	235-508.	25.i.1925.	
		3.	509-718.	30.vi.1925.	
		4.	719-928.	15.xii.1925.	
		5 (1&2).	i-xxxviii.	1925.	
		5 (3&4).	i-xxx.	1926.	
—	XXXI.	1.	1-232.	15.v.1926.	Part 5 (3&4) contained 2 sets of un-numbered pages at the end with the following papers, "Geometridae from Upper Burma" (p. 1) and "Notes on the birds of the Sikkim Himalayas. Additions and corrections. Volume XXIX" by H.S. (3 leaves). *These dates were written by hand on copies received at the Secunderabad Club Library, Secunderabad, Andhra Pradesh.
		2.	233-532.	15.viii.1926.	
		3.	533-832.	1.xi.1926.	
		4.	833-1042.	20.ii.1927.	
		5 (1&2).	i-xxxii.	18.x.1927*.	
		5 (3&4).	i-lxxiv, 1, 3.	26.xi.1927*.	
—	XXXII.	1.	1-236.	1.viii.1927.	
		2.	237-396.	20.x.1927.	
		3.	397-616.	15.i.1928.	
		4.	617-817.	31.v.1928.	
		5 (1&2).	i-xxix.	1928.	
		5 (3&4).	i-xxxi.	1928.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
—	XXXIII.	1.	1-221.	30.ix.1928.	
		2.	222-471.	15.ii.1929.	
		3.	473-744.	30.v.1929.	
		4.	745-1005.	15.x.1929.	
		5 (1&2).	i-xxxii.	1929.	
		5 (3&4).	i-lxxxi.	1929.	
—	XXXIV.	1.	1-269.	1.iii.1930.	
		2.	271-611.	15.vii.1930.	
		3.	613-858.	15.xi.1930.	
		4.	859-1104.	2.iii.1931.	
		5 (1&2).	i-xlv.	1930.	
		5 (3&4).	i-lxxiv.	1931.	
—	XXXV.	1.	1-240.	15.vi.1931.	Part 2 had an insert-slip "Notice" to members from the Editors, "Records of Duck and Snipe schedules." Also a tear away page, "Form of Bequest."
		2.	241-474.	15.x.1931.	
		3.	475-702.	15.ii.1932.	
		4.	703-926.	15.vii.1932.	
		5 (1&2).	i-xxxv.	1932.	
		5 (3&4).	i-lviii.	1933.	
—	XXXVI.	1.	1-291.	15.xi.1932.	Part 4 contained the following additional papers at the end, with different pagination: "The wild animals of the Indian Empire and the Problem of their Preservation. Part I," with a foreword by His Excellency the Viceroy [Willingdon], and Introduction (pp. 1-11) by S.H. Prater (a reprint of the address given by him at the Jubilee Meeting of the Society, held in Bombay on August 10, 1933), pp. iv leaves, 1-39. "The preservation of wild life in India. No. 1. *The Central Provinces*" by A.A. Dunbar-Brander, p. 40-45, and "No. 2. *The Bombay Presidency*" by G. Monteath, p. 46-58. An insert-slip from the Editors informed "the concluding parts of Mr. Stuart Baker's series on Indian Semi-Sporting Birds will appear in the next issue."
		2.	293-520.	15.iv.1933.	
		3.	521-777.	15.viii.1933.	
		4.	778-1025.	15.xii.1933.	
		5 (1&2).	i-xxxiv.	1933.	
		5 (3&4).	i-lxv.	1934.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
—	XXXVII.	1.	1-244.	15.iv.1934.	Part 1 contained the following additional papers (continued from Vol. XXXVI No. 4) at the end, with different pagination: "The wild animals of the Indian Empire and the Problem of their Preservation. Part II," pp. 59-96. "The preservation of wild life in India. No. 3. *Assam*," by A.J.W. Milroy, pp. 97-104, and "No. 4. *The United Provinces*," by F.W. Champion, pp. 105-111. Part 3 contained an insert-slip informing that Part III of the series, "Wild animals of the Indian Empire," would appear in the next issue. Part 4 contained 3 additional papers (continued from Vol. XXXVII No. 1) at the end, with different pagination: "The wild animals of the Indian Empire and the Problem of their Preservation. Part III," pp. 112-161. "The preservation of wild life in India. No. 5. The Indian Lion," by Sir Patrick Cadell, pp. 162-166, and "No. 6. Wild life protection in Burma" by H.C. Smith, pp. 167-188.
		2.	245-512.	15.viii.1934.	
		3.	513-748.	15.xii.1934.	
		4.	749-967.	15.iv.1935.	
		5 (1&2).	i-xxxv.	1935.	
		5 (3&4).	i-lxiv.	1935.	
—	XXXVIII.	1.	1-228.	15.viii.1935.	Part 2 contained the following additional papers (continued from Vol. XXXVII No. 4) at the end, with different pagination: "The wild animals of the Indian Empire and the Problem of their Preservation. Part IV," pp. 187-219. "The preservation of wild life in India. No. 7. The Madras Presidency," by R.D. Richmond, pp. 220-224; "Comments on Mr. Richmond's note," by R.C. Morris, pp. 225-230; "No. 8. Hyderábád State," by Sálim Ali, pp. 231-240; and "No. 9. Mysore," by E.G. Phythian-Adams, pp. 241-245.
		2.	229-414.	1.xii.1935.	
		3.	415-646.	15.iv.1936.	
		4.	647-835.	25.viii.1936.	
		5 (1&2).	i-xxxv.	1936.	
		5 (3&4).	i-xxiv.	1937.	
—	XXXIX.	1.	1-198.	1.xii.1936.	
		2.	199-430.	15.iv.1937.	
		3.	431-658.	25.ix.1937.	
		4.	659-881.	15.xii.1937.	
		5 (1&2).	i-xxvi.	1937.	
		5 (3&4).	i-xxxi.	1938.	
1938.	XL.	1.	1-136, 1-70.	iv.1938.	An insert-slip from the Editors, apologising for the delay of publication of Parts 2 & 4 due to a labour trouble at the press. Part 1 contains a "General Index of Subjects and Authors for Vols. XXXI-XXXVI Inclusive," (pp. 1-70).
1938.		2.	137-354.	ix.1938.	
1938.		3.	355-582.	xii.1938.	
1939.		4.	583-777.	v.1939.	
		5 (1&2).	i-xxviii.	1939.	
		5 (3&4).	i-lvi.	1939.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
1939.	XLI.	1.	1-202.	viii.1939.	
1939.		2.	203-452.	xii.1939.	
1940.		3.	453-680.	viii.1940.	
1940.		4.	681-910.	xii.1940.	
		5 (1&2).	i-xxiv.	1940.	
		5 (3&4).	i-liv.	1941.	
1940.	XLII.	1.	1-232.	xii.1940.	
1941.		2.	233-454.	iv. 1941.	
1941.		3.	455-684.	viii.1941.	
1941.		4.	685-944.	xii.1941.	
		5 (1&2).	i-xxxii.	1942.	
		5 (3&4).	i-lix.	1942.	
1942.	XLIII.	1.	1-114.	iv.1942.	
1942.		2.	115-290.	viii.1942.	
1942.		3.	291-537.	xii.1942.	
1943.		4.	539-680.	iv.1943.	
		5 (1&2).	?	?	
		5 (3&4).	i-xxix.	20.iii.1947.	
1943.	XLIV.	1.	1-158.	viii.1943.	Part 3 had an insert-slip, "To Members: It is regretted that owing to present-day conditions there has been unavoidable delay in publishing this Journal. Every effort is being made to maintain the standard of the Journal and to issue it to members as regularly as possible. The Index to Vol. XLIII, Nos. 3 and 4, has been lost at sea and will be published later. —Editors." Part 4 had an insert-slip, "To Members: The recent Paper Control (Economy) Order of the Government of India compels the Society to limit its Journal to an issue of 120 pages inclusive of illustrations, cover and index. We express our regrets to members and to contributors, publication of whose articles is necessarily delayed. —Editors."
1943.		2.	159-314.	xii.1943.	
1944.		3.	315-498.	iv.1944.	
1944.		4.	499-606.	viii.1944.	
		5 (1&2).	i-xxv.	20.viii.1947.	
		5 (3&4).	i-xxvi.	5.xii.1947.	
1944.	45.	1.	1-96.	xii.1944.	This volume onwards, the volume number was changed from Roman to Arabic. Parts 3 and 4 have the date of publication and, "1,250 copies," in the colophon at the bottom of the back cover.
1945.		2.	97-262.	iv.1945.	
1945.		3.	263-450.	22.x.1945.	
1945.		4.	451-624.	20.xii.1945.	
		5 (1&2).	i-xx.	7.viii.1948.	
		5 (3&4).	i-xxiii.	1949.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
1946.	46.	1.	1-204.	20.vi.1946.	Editors inserted a slip apologising for the delay of publication of Part 2, due to labour trouble at the press. Part 4, "1,300 copies."
1946.		2.	205-410.	10.xii.1946.	
1946.		3.	411-566.	27.iii.1947.	
1947.		4.	567-746.	18.viii.1947.	
		5 (1&2).	i-xx.	1949.	
		5 (3&4).	i-xxxi.	8.xi.1949.	
1947.	47.	1.	1-194.	17.xi.1947.	Part 4 contained a "Catalogue of books in the Bombay Natural History Society's Library. Part I—Mammals," (pp. 797-804).
1947.		2.	195-400.	9.iv.1948.	
1948.		3.	401-564.	22.vi.1948.	
1948.		4.	565-804.	3.xii.1948.	
		5 (1&2).	i-xxxiii.	28.xi.1950.	
		5 (3&4).	i-xli.	15.v.1951.	
1948.	48.	1.	1-200.	25.iv.1949.	The colour of the covers of the *Journal* for the Vols I-48 varied from light brown to grey or green. Part 2 contained a "Catalogue of books in the Bombay Natural History Society's Library. Part II—Birds," (pp. 383-398). Part 3 contained a "Catalogue of books in the Bombay Natural History Society's Library. Part III—Reptiles, Amphibians & Fishes," (pp. 631-643).
1949.		2.	201-398.	23.vii.1949.	
1949.		3.	399-644.	17.xi.1949.	
1949.		4.	645-816	31.i.1950.	
		5 (1&2).	i-xli.	26.ix.1951.	
		5 (3&4).	i-xxxii.	5.i.1952.	
1950.	49.	1.	1-136.	31.i.1950.	The colour of the cover changed to yellow from this volume onwards. Part 2 contained a "Catalogue of books in the Bombay Natural History Society's Library. Part IV—Entomology," (pp. 324-354). Part 4 contained the "Bombay Wild Animals and Wild Birds Protection Act 1951," by the Editors (pp. 815-832).
1950.		2.	137-354.	viii.1950.	
1950.		3.	355-596.	xii.1950.	
1951.		4.	597-832.	4.vi.1951.	
		5 (1&2).	i-xxvii.	15.v.1952.	
		5 (3&4).	i-xxxv.	30.xii.1952.	
1951.	50.	1.	1-210.	28.ix.1951.	Part 1 contained a "Catalogue of books in the Bombay Natural History Society's Library. Part V—Invertebrata," (pp. 187-192) and, "Catalogue of books in the Bombay Natural History Society's Library. Part VI—Botany," (pp. 193-210). Part 4 is a "Special 50th Anniversary Issue of the Journal." It contains an editorial (pp. 691-704) with an Editor's Who's Who, costs of printing and a proposal to rechristen the *Journal* as "Hornbill" or "Garuda" for the sake of brevity.
1951.		2.	211-450.	5.i.1952.	
1952.		3.	451-690.	20.v.1952.	
1952.		4.	691-964.	23.viii.1952.	
		5 (1&2).	i-xxxii.	14.ix.1953.	
		5 (3&4).	i-xxxvii.	1954.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
1952.	51.	1.	1-338.	30.xii.1952.	
1953.		2.	339-530	24.iv.1953.	
1953.		3.	531-764.	19.ix.1953.	
1953.		4.	765-986.	3.ii.1954.	
		5 (1&2).	???	???	
		5 (3&4).	i-xxxii.	1955.	
1954.	52.	1.	1-232.	1.vii.1954.	Part 2&3 was the only combined issue of the *JBNHS*.
1954.		2&3.	233-686.	23.xii.1954.	
1955.		4.	687-962.	24.iv.1955.	
		Index.	i-lxiv.	1958.	
1955.	53.	1.	1-162.	26.viii.1955.	
1955.		2.	163-314.	20.i.1956.	
1956.		3.	315-514.	30.v.1956.	
1956.		4.	515-752.	28.viii.1956.	
		Index.	i-lxii.	1962.	
1956.	54.	1.	1-250.	20.xii.1956.	
1957.		2.	251-490.	3.vi.1957.	
1957.		3.	491-810.	14.x.1957.	
1957.		4.	811-994.	24.xii.1957.	
		Index.	i-lv.	1972.	
1958.	55.	1.	1-194.	7.vi.1958.	The colour of the cover changed to yellow and black from this volume onwards. Part 3 had an insert-slip with the following, "*This part completes the present volume. In future each volume will consist of the three parts issued during the calendar year.*"
1958.		2.	195-406.	25.ix.1958.	
1958.		3.	407-602.	8.i.1959.	
		Index.	i-xxxviii.	1971.	
1959.	56.	1.	1-164.	15.v.1959.	
		2.	165-374.	24.x.1959.	
		3.	375-698.	18.ii.1960.	
		Index.	i-xlvii +1.	1974.	
1960.	57.	1.	1-244.	6.vii.1960.	
		2.	245-463.	24.x.1960.	
		3.	465-719.	5.i.1961.	
		Index.	1-39.	1972.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
1961.	58.	1.	1-320.	29.vii.1961.	Part 2 had a tear away "Corrigenda. Vol. 58, No. 1 – April 1961" insert-slip. Part 3 had an insert-slip with a "For Sale" notice of "One .410 S.B.B.L. collecting shot-gun, Belgian make, together with ammunition."
		2.	321-558.	11.xi.1961.	
		3.	559-854.	8.ii.1962.	
		Index.	i-lxiii.	1968.	
1962.	59.	1.	1-334.	17.vii.1962.	
		2.	335-706.	28.xi.1962.	
		3.	707-1000.	25.iii.1963.	
		Index.	i-lxxxix.	1968.	
1963.	60.	1.	1-300.	13.vii.1963.	From this volume onwards, "Date of Publication" was printed on the Contents page, in addition to being inserted in the colophon at the bottom of the last page of each Part. Part 1 had an insert-slip informing that, "The concluding section of A. Brosset's serial on 'The Bats of Western and Central India' will appear in the August 1963 issue of the *Journal* (Vol. 60, No. 2)."
		2.	301-506.	12.xi.1963.	
		3.	507-767.	14.iv.1964.	
		Index.	i-lx.	?	
1964.	61.	1.	1-246.	25.viii.1964.	
		2.	247-482.	23.xii.1964.	
		3.	483-726.	10.vi.1965.	
		Index.	i-xl.	1980.	
1965.	62.	1.	1-192.	31.vii.1965.	Part 1 had an insert-slip "Notice: to purchasers of S.H. Prater's THE BOOK OF INDIAN ANIMALS, 2nd (Revised) Edition. Through an oversight entries relating to CHAPTER 12. BATS were not included in the Index. On receipt of an addressed envelope (p.c. size) bearing a 10 P. stamp the undersigned will be glad to send a slip correcting the omission to any purchaser who has not already been supplied with it," (sd., Hon. Secretary). Another insert-slip, "Errata," related to a paper in Vol. 61(2): 402-409. This part also contains Dr. Sálim Ali's speech, delivered on the occasion of "The Opening of Hornbill House: 13-3-1965," (pp. 185-191).
		2.	193-378.	30.xi.1965.	
		3.	379-612	26.iv.1966.	
		Index.	i-xxxiii.	1982.	
1966.	63.	1.	1-234.	12.x.1966.	Part 1 had an insert-slip, "Correction Slip: In Vol. 62 on p. 609, in fifth line under heading 'Nicobar Bird Survey', for '1965' read '1966'." Part 3 was a special "Wild Life Issue."
		2.	235-488.	27.iii.1967.	
		3.	489-791.	20.vii.1967.	
		Index.	i-xxvii.	1983.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
1967.	64.	1.	1-138.	15.vii.1967.	
		2.	139-403.	18.x.1967.	
		3.	405-612.	22.i.1968.	
		Index.	i-xl.	1984.	
1968.	65.	1.	1-282.	31.v.1968.	
		2.	283-532.	6.xi.1968.	
		3.	533-827.	28.v.1969.	
		Index.	i-xlvii.	1985.	
1969.	66.	1.	1-237.	19.xi.1969.	
		2.	239-422.	30.xii.1969.	
		3.	423-692.	20.vi.1970.	
		Index.	i-xxxii.	1971.	
1970.	67.	1.	1-135.	30.vi.1970.	Part 3 was a Fr. Santapau Commemorative Number.
		2.	137-364.	31.x.1970.	
		3.	365-646.	25.iii.1971.	
		Index	i-xxv.	1972.	
1971.	68.	1.	1-306.	15.ix.1971.	
		2.	307-502.	29.xi.1971.	
		3.	503-886.	26.ii.1972.	
		Index.	i-xliv.	1973.	
1972.	69.	1.	1-254, 1-94.	18.ix.1972.	Part 1 contained a "General Index of Subjects and Authors for Vols. 43-53 Inclusive," (pp. 1-93). Part 3 had an insert-slip, "Notice: There may be considerable delay in the publication of the April issue of the *Journal* Volume 70 (1) in view of the serious power shortage in Madras where the Society's Journals are printed."
		2.	255-460.	11.xii.1972.	
		3.	461-714.	27.vi.1973.	
		Index.	i-xl.	1975.	
1973.	70.	1.	1-244.	6.xii.1973.	Part 3 had "An Appeal. Scientific Collections and Endowments," on the last page (unnumbered).
		2.	245-416.	15.ii.1974.	
		3.	417-630 +1.	18.x.1974.	
		Index.	i-xliv.	1976.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
1974.	71.	1.	1-182.	21.x.1974.	Part 3 was a Festschrift for Dr. Sálim Ali.
		2.	183-350.	20.ii.1975.	
		3.	351-666.	10.iii.1976.	
		Index.	i-xlvii.	1986.	
1975.	72.	1.	1-242.	30.iv.1975.	The single column layout, that was followed by the *Journal*, ended with this volume. Part 1 contained an insert-slip from the Editors, "The publication of the December issue for 1974 Vol. 71 (3) is delayed owing to acute power shortage in Madras, where the Journal is in press." A new section, "New Descriptions," was started from Part 3.
		2.	243-621.	31.i.1976.	
		3.	623-918.	13.viii.1976.	
1976.	73.	1.	1-248.	22.xii.1976.	The dimensions (page size) of the *Journal* increased slightly and a double column layout was adopted from this volume onwards. The colour of the cover also changed to yellow and brown from this volume.
		2.	249-432.	28.iii.1977.	
		3.	433-588.	5.xii.1977.	
1977.	74.	1.	1-212.	12.viii.1977.	Suppl. = Supplementary Issue. This was the first ever Suppl. to the *JBNHS*.
		2.	213-400.	14.iii.1978.	
		3.	401-579.	27.xi.1978.	
		Suppl.	581-697.	27.iii.1979.	
1978.	75.	1.	1-255.	7.viii.1978.	Part 3 is the "75th Jubilee Year 1886-1979" issue. On the Contents page it is called the "Diamond Jubilee Issue." An Editorial (pp. i-iii) comments on the contemporary trend of papers and articles in the *JBNHS vis-à-vis* when it had commenced publication in 1886. It also contains "The Editors' Who's When, The Editors' Who's Who and, Costs then and now."
		2.	257-558.	2.ii.1979.	
		3.	559-947.	22.x.1979.	
		Suppl.	949-1267.	27.iii.1980.	
1979.	76.	1.	1-218.	12.ii.1980.	
		2.	219-377.	28.iv.1980.	
		3.	379-564.	18.viii.1980.	
1980.	77.	1.	1-199.	29.xi.1980.	Part 2: The colour of the cover changed to brown from this Part onwards.
		2.	201-370.	28.iii.1981.	
		3.	371-566.	27.iv.1981.	
1981.	78.	1.	1-200.	15.v.1981.	
		2.	201-428.	28.viii.1981.	
		3.	429-666.	28.xii.1981.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
1982.	79.	1.	1-240.	26.vii.1982.	
		2.	241-492.	15.ii.1983.	
		3.	493-750.	28.iii.1983.	
		Index.	i-lxxv.	1984.	
1983.	80.	1.	1-272.	28.xi.1983.	
		2.	273-468.	27.ii.1984.	
		3.	469-696.	24.iv.1984.	
		Index.	i-xlix.	?	
1984.	81.	1.	1-242.	9.viii.1984.	
		2.	243-536.	16.xi.1984.	
		3.	537-743.	28.i.1985.	
1985.	82.	1.	1-248.	29.iv.1985.	
		2.	249-448.	23.ix.1985.	
		3.	449-731.	18.ii.1986.	
		Index.	i-lii.	?	
1986.	83.	1.	1-282.	30.vi.1986.	Part 1 had an insert-slip, "Errata. On p. 1 of *Journal* Vol. 83, No. 1, for August 1986, *read* April 1986." The Suppl., is "Centenary Supplement 1886-1986." On Contents page it was called "Centenary Issue 1886-1986." This Supplement had a blank card cover without the usual logo, title, etc., of the *JBNHS*. Of interest in it, was a paper by Sálim Ali (pp. 1-6) entitled "The Journal: Its role in Indian natural history." Also an Appendix (pp. 233-238) with details of Editors of the *Journal*, their tenure and brief biographies.
		2.	283-476.	27.ix.1986.	
		3.	477-734.	25.v.1987.	
		Suppl.	1-238.	13.iv.1987.	
1987.	84.	1.	1-268.	15.x.1987.	
		2.	269-504.	20.ii.1988.	
		3.	505-760.	25.v.1988.	
1988.	85.	1.	1-250.	20.viii.1988.	Part 3, pp. 1-31 consisted of the 104th Annual Report & Accounts, 1987. (Earlier, such statements were paginated in continuation with the main Part.)
		2.	251-464.	20.xii.1988.	
		3.	465-698, 1-31.	20.ii.1989.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
1989.	86.	1.	1-124.	14.viii.1989.	The Editorial (frontispiece!) stated, "The Journal of the BNHS begins its 86th year with a new look. A board of editors, consisting of leading experts in their respective fields of interest, has been constituted...We have moved from the traditional letterpress printing to the offset process...Page composing will now be done in-house, using computer software...We have been able to reduce the number of pages...without reducing the amount of text." The colour of the cover changed from the usual shade of yellow/mustard to shades of green. In Part 3, pp. 1-30 consisted of the 105th Annual Report & Accounts, 1988-89. Each Part of this Volume had at its end a list entitled "Index of Authors, Miscellaneous Notes." This comprised of addresses of authors of Miscellaneous Notes, which up till then were published below the pertinent Miscellaneous Note in the body of the *Journal*.
		2.	125-279 +3.	15.xii.1989.	
		3.	281-483 +3, 1-30.	30.iii.1990	
1990.	87.	1.	1-174 +2.	30.vi.1990.	Part 3, pp. 1-34, comprised of 107th AGM Report & Accounts.
		2.	175-334 +2.	30.x.1990.	
		3.	337-474 +6,1-34.	20.ii.1991.	
1991.	88.	1.	1-143 +3.	31.viii.1991.	
		2.	145-313 +3.	1 ii.1992.	
		3.	315-470 +2.	1.iii.1992.	
1992.	89.	1.	1-152 +2.	30.vi.1992.	
		2.	153-276 +2.	31.x.1992.	
		3.	277-395 +2.	30.i.1993.	
1993.	90.	1.	1-140.	15.iv.1993.	Cover colour of the *Journal* changed from green (Part 1) to laminated white card (Parts 2 and 3). Design of the cover also changed. The "Index of Authors, Miscellaneous Notes," carried illogically and inconveniently in Vols 86-89 is discontinued and addresses of authors of Miscellaneous Notes now appear below the pertinent Note.
		2.	141-370.	24.i.1994.	
		3.	371-552.	1.vi.1994.	
1994.	91.	1.	1-172.	1.viii.1994.	
		2.	173-354.	29.xi.1994.	
		3.	355-524.	1.iii.1995.	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
1995.	92.	1.	1-150.	24.iv.1995.	
		2.	151-294.	1.viii.1995.	
		3.	295-444.	1.xii.1995.	
1996.	93.	1.	1-166.	1.iv.1996.	Part 1: In the Contents (p.iii), the sub-head 'Plants' is omitted on the top right hand column under "Miscellaneous Notes" for the botany articles cited after 'Insects', (Nos. 30-40). Part 3: Misprinted as "Volume 93 (1): December 1996" on the Contents page (p. ii). Carried an Editorial (p. i). This was a "Dr Sálim Ali Centenary Issue." Two papers on him were in the preliminary pages. "Dr. Sâlim Ali's contribution to Kutch Ornithology" by M.K. Himmatsinhji (pp. v-vii), and, "Sálim Ali" by Lady Y.P. McNeice (p. viii, with a colour photo of Sálim Ali).
		2.	167-330.	5.viii.1996.	
		3.	331-600.	1.xii.1996.	
1997.	94.	1.	1-231.	1.iv.1997.	The dates of publication, from this volume onwards, mentioned on the Contents page, may not have been the actual dates of publication.
		2.	233-450.	1.viii.1997.	
		3.	451-602.	1.xii.1997.	
1998.	95.	1.	1-192.	1.iv.1998.	The dates in brackets are the dates of the *Journal* 'Delivery Challans' given by the press.
		2.	193-376.	1.viii.1998.	
		3.	377-543.	1.xii.1998. [31.xii.1998]	
1999.	96.	1.	1-183.	1.iv.1999. [18.v.1999]	The cover of the *Journal* sported a colour photograph from Part 1 onwards. An "Editorial" was added from Part 1.
		2.	185-361.	1.viii.1999. [6.ix.1999]	
		3.	363-506.	1.xii.1999. [23.xii.1999]	
2000.	97.	1.	1-174.	1.iv.2000. [25.v.2000]	Part 1 Last numbered page was 171 + Errata & Corrigenda 3 pp.
		2.	175-315.	1.viii.2000 [27.ix.2000]	
		3.	317-460.	1.xii.2000. [20.ii.2001]	

Table 1: The dates of publication of the *Journal of the Bombay Natural History Society* (*contd.*)

Year.	Volume.	Part.	Pages.	Date of publication.	Notes.
2001.	98.	1.	1-158.	1.iv.2001. [15.vi.2001]	Part 2 had a frontispiece. The front cover was with a colour graphic that was flush with the edges. Part 3 had a similar cover style as the earlier Part.
		2.	159-322.	1.viii.2001 [27.x.2001]	
		3.	323-502.	1.xii.2001. [26.ii.2002]	
2002.	99.	1.	1-160.	1.iv.2002. [3.vi.2002]	Part 1 reverted its cover layout to that of Vol. 98 No. 1. Part 2 onwards, the actual date of publication was printed once again in the colophon. Part 3 Preliminary pages have an acknowledgement and a notice from the editors. The last page consists of Errata in Vol. 99(2), August 2002.
		2.	161-386.	6.ix.2002	
		3.	2 +387-590 +2	28.ii.2003	
2003.	100.	1.	1-166	17.vii.2003	Part 1: Preliminary pages have an acknowledgement and a notice from the Editors. Part 2 and Part 3 have been combined in this Centenary Journal. Preliminary pages include acknowledgements.
		2&3.	167-640	23.ix.2003	

ACKNOWLEDGEMENTS

I would like to thank V. Nagulu and C. Srinivasulu of the Zoology Department of Osmania University, and the staff of the Osmania University College of Science Library, Hyderabad. I would also like to thank J.C. Daniel, A.R. Rahmani and the library staff at Bombay Natural History Society, Siraj A. Taher of the Birdwatchers' Society of Andhra Pradesh and Alison Harding, Assistant Librarian at the Ornithology and Rothschild Libraries, Natural History Museum, Tring, England. All of them helped in various ways while I was compiling this paper. Edward C. Dickinson of The Trust for Oriental Ornithology, Murray Bruce and especially, Kumar Ghorpadé (who generously sent "additional notes" on the *Journal*, for inclusion), sent their comments on an earlier draft of the paper, for which I am indeed grateful. (Mrs.) Rafia Abdulali and Akbar Abdulali permitted access to late Humayun Abdulali's library in Mumbai, where his properly bound volumes of the *Journal* were a source of vital information.

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Appendix I: List of published general indices of subjects and authors

Volumes covered	Published in Volume	Year of Publication
I-XIII	XIII (5)	1901
XIV-XVII	XVII (5)	1907
XVIII-XXIV	XXIV (5)	1917
XXV-XXX	XXXII / XXXIII [1]	1928*
XXXI-XXXVI	XL (1)	1938
XXXVII-XLII	48 [2]	1949*
43-53	69 (1)	1972
54-63	72 / 73 [3]	1976*

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[1] This General Index was published separately as a stand-alone volume (pp. 1-53), and must have been despatched either with Vol. XXXII or XXXIII, printed in 1928.

[2] This General Index was published separately on "1-6-1949" as a stand-alone volume (pp. 1-48), and must have been despatched with Vol. 48, which was printed in 1949.

[3] This General Index was published separately as a stand-alone volume (pp. 1-53), and must have been despatched either with Vol. 72 or 73, printed in 1976.

* These days have been taken from a bound volume of indices available with the librarian at the Bombay Natural History Society.

Appendix II: The Editors of the Society's *Journal* *

Volume	Year	Editor / Editors / Board of Editors
I-II.	1886-1887.	R.A. Sterndale & E.H. Aitken.
III-XI.	1888-1897.	H.M. Phipson.
XII-XVI.	1898-1904.	H.M. Phipson & W.S. Millard.
XVII.	1907.	W.S. Millard, E.H. Comber & L.C.H. Young.
XVIII-XXVI.	1907-1918.	W.S. Millard, R.A. Spence & N.B. Kinnear.
XXVII-XXIX.	1920-1923.	R.A. Spence, B.C. Ellison & S.H. Prater.
XXX.	1924.	R.A. Spence, P.M.D. Sanderson & S.H. Prater.
XXXI.	1926.	R.A. Spence & S.H. Prater.
XXXII.	1927-1928.	R.A. Spence, P.M.D. Sanderson, S.H. Prater & Sálim Ali.
XXXIII.	1928-1929.	R.A. Spence, S.H. Prater & Sálim Ali.
XXXIV-XXXV.	1930-1932.	R.A. Spence & S.H. Prater.
XXXVI-XXXVII.	1932-1934.	R.A. Spence, P.M.D. Sanderson, S.H. Prater & C. McCann.
XXXVIII-XL.	1935-1939.	M.J. Dickins, P.M.D. Sanderson, S.H. Prater, C. McCann, H.M. McGusty & J.F. Caius.
XLI-XLIII.	1939-1943.	H.M. McGusty, J.F. Caius & S.H. Prater.
XLIV.	1943-1944.	J.F. Caius, S.H. Prater & C. McCann.
45 - 47(3).	1944-1948.	S.H. Prater, C. McCann & Sálim Ali.
47(4) - 48(2).	1948-1949.	Sálim Ali & S.B. Setna.
48(3) - 51.	1949-1953.	Sálim Ali, S.B. Setna & H. Santapau.
52-56.	1954-1959.	Sálim Ali & H. Santapau.
57-59.	1960-1962.	Sálim Ali, H. Santapau & H. Abdulali for Vol. 57 No. 1. H. Santapau & H. Abdulali for the rest.
60-61.	1963-1964.	H. Santapau & Z. Futehally.
62-63.	1965-1966.	H. Santapau, D.E. Reuben, Z. Futehally & J.C. Daniel.
64-67.	1967-1970.	H. Santapau, Z. Futehally & J.C. Daniel.
68-70.	1971-1973.	Z. Futehally, J.C. Daniel & P.V. Bole.

Appendix II: The Editors of the Society's *Journal* * *(contd.)*

Volume	Year	Editor / Editors / Board of Editors
71-85.	1974-1988.	J.C. Daniel, P.V. Bole & A.N.D. Nanavati. M. Gadgil & R.B. Grubh edited the Supplement to Vol. 75.
86(1).	1989.	J.C. Daniel (Executive Editor), A. Varadachary (Assistant Editor), P.V. Bole & M.R. Almeida (Botany), B.F. Chhapgar (Pisces, Marine Biology), R. Whitaker (Herpetology), H. Abdulali & R.M. Naik (Ornithology), A.J.T. Johnsingh (Mammalogy) & B.V. David (Entomology).
86(2) - 88(2).	1989-1991.	J.C. Daniel (Executive Editor), A. Varadachary (Assistant Editor), H. Abdulali, M.R. Almeida, P.V. Bole, B.F. Chhapgar, B.V. David, A.J.T. Johnsingh, R.M. Naik & R. Whitaker.
88(3) - 89(2).	1991-1992.	J.C. Daniel (Executive Editor), A. Varadachary (Assistant Editor), M.R. Almeida, P.V. Bole, B.F. Chhapgar, B.V. David, A.J.T. Johnsingh, & R. Whitaker.
89(3).	1992.	J.C. Daniel (Executive Editor), A. Varadachary (Assistant Editor), M.R. Almeida, P.V. Bole, M.K. Chandrashekaran, B.F. Chhapgar, B.V. David, R. Gadagkar, A.J.T. Johnsingh, Ajith Kumar, A.R. Rahmani, J.S. Samant, J.S. Serrao, E.G. Silas, J.S. Singh & R. Whitaker.
90(1).	1993.	J.C. Daniel (Executive Editor), A. Varadachary (Assistant Editor), M.R. Almeida, P.V. Bole, M.K. Chandrashekaran, B.F. Chhapgar, B.V. David, R. Gadagkar, Anil Gore, A.J.T. Johnsingh, Ajith Kumar, A.R. Rahmani, J.S. Samant, J.S. Serrao, E.G. Silas, J.S. Singh & R. Whitaker.
90(2).	1993.	J.C. Daniel (Executive Editor), M.R. Almeida, P.V. Bole, M.K. Chandrashekaran, B.F. Chhapgar, B.V. David, R. Gadagkar, Anil Gore, A.J.T. Johnsingh, Ajith Kumar, A.R. Rahmani, J.S. Samant, J.S. Serrao, E.G. Silas, J.S. Singh & R. Whitaker.
90(3).	1993.	J.C. Daniel (Executive Editor), K.P. Shirodkar (Assistant Editor), M.R. Almeida, P.V. Bole, M.K. Chandrashekaran, B.F. Chhapgar, B.V. David, R. Gadagkar, Anil Gore, A.J.T. Johnsingh, Ajith Kumar, A.R. Rahmani, J.S. Samant, J.S. Serrao, E.G. Silas, J.S. Singh & R. Whitaker.
91 - 93(2).	1994-1996.	J.C. Daniel (Executive Editor), K.P. Shirodkar (Assistant Editor), M.R. Almeida, P.V. Bole, M.K. Chandrashekaran, B.F. Chhapgar, B.V. David, R. Gadagkar, Anil Gore, A.J.T. Johnsingh, Ajith Kumar, A.R. Rahmani, J.S. Samant, E.G. Silas, J.S. Singh & R. Whitaker.
93(3) - 94(3).	1996-1997.	J.C. Daniel (Executive Editor), Gayatri Wattal Ugra (Assistant Editor), M.R. Almeida, P.V. Bole, M.K. Chandrashekaran, B.F. Chhapgar, B.V. David, R. Gadagkar, Anil Gore, A.J.T. Johnsingh, Ajith Kumar, A.R. Rahmani, J.S. Samant, E.G. Silas, J.S. Singh & R. Whitaker.
95(1) - 95(3).	1998.	J.C. Daniel (Editor), Gayatri Wattal Ugra (Assistant Editor), M.R. Almeida, P.V. Bole, M.K. Chandrashekaran, B.F. Chhapgar, B.V. David, R. Gadagkar, Anil Gore, A.J.T. Johnsingh, Ajith Kumar, A.R. Rahmani, J.S. Samant, E.G. Silas, J.S. Singh & R. Whitaker.
96(1) to date.	1999 to date.	J.C. Daniel (Editor), Gayatri Wattal Ugra (Assistant Editor), M.R. Almeida, M.K. Chandrashekaran, B.F. Chhapgar, R. Gadagkar, Indraneil Das, A.J.T. Johnsingh, Ajith Kumar, T.C. Narendran, A.R. Rahmani, J.S. Singh & R. Whitaker.

*With additions and corrections to the list in Anon. 1987.

■ ■ ■

OBITUARY

HUMAYUN ABDULALI

THE Society lost a valued member and a link to the past, in the death of Mr. Humayun Abdulali on June 3, 2001. Humayun and Sálim Ali were responsible for the rejuvenation and relaunching of the Society when India attained Independence and the majority of the Society's supporters left India. They nursed the Society during this difficult period, and during the nearly ten years that he was the Honorary Secretary, Humayun saw to it that the Society again had a solid foundation in the study of Indian Natural History. Working in tandem with Sálim Ali, he ensured that the Society had the crucial support of the State and Central governments in assuring that land and funds were made available for housing the Society and its invaluable collections, and continued publication of the *Journal*, which was at that point of time the main activity of the Society.

Humayun was born on May 19, 1914 in Kobe, Japan, where his father was associated in the business of a relative. The family returned to India and settled in Mumbai in 1925. He was a student of St. Xavier's High School and later St. Xavier's College where he obtained his B.A. degree in Biology. His association with Br. Navarro of St. Xavier's High School, started his life long interest in Natural History.

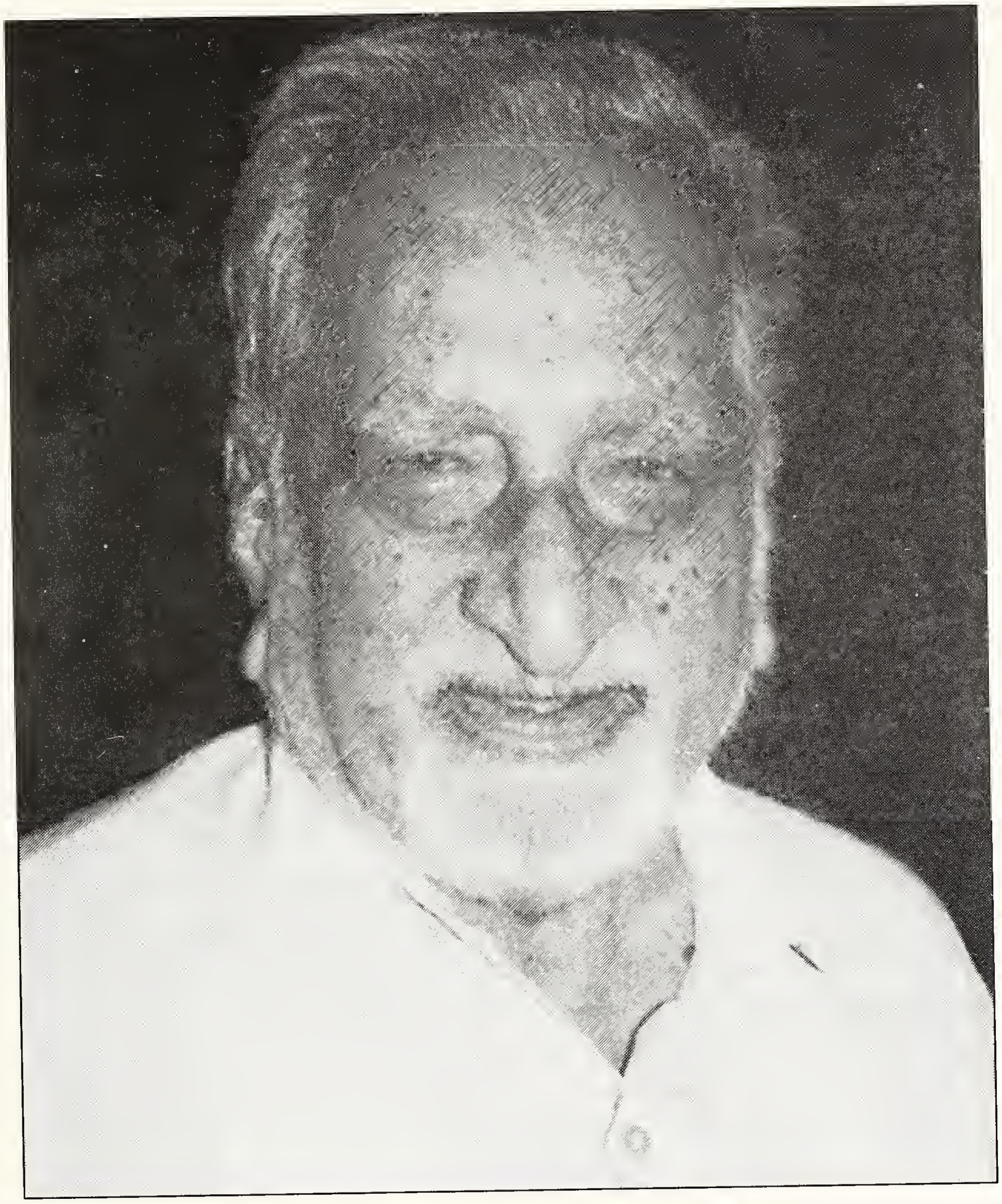
Humayun was, above all, an incomparable naturalist. His interest covered all aspects of natural history and nothing was too insignificant to be denied his attention.

His significant scientific contributions include cataloguing the collection of birds at the BNHS and the study of the bird fauna of the Andaman and Nicobar Islands. The nearly three hundred papers he published reflect the wide scope of his interest in Indian Natural History.

He made significant pathbreaking contributions to the conservation of India's wildlife heritage. The drafting of the Bombay Wild Bird and Wild Animals Protection Act in 1951, the basic source for the Wildlife Protection Act passed in 1972, the filing of the first Public Interest litigation, which saved the Borivli National Park in Bombay from being destroyed by a highway, and the ban on the export of frog's legs and junglefowl hackles are peaks in the conservation movement in the country.

As a person, he had neither time nor patience to suffer the pretentious, and did not fail to express his opinion. He was warm hearted and a true friend to those who penetrated his armour of brusqueness. He was, above all, a person of impeccable integrity, a character which he and Sálim Ali bequeathed to the Society, their foster child.

■ J.C. DANIEL



HUMAYUN ABDULALI
(1914-2001)

MISCELLANEOUS NOTES

1. DOGS *CANIS FAMILIARIS* HUNTING THE INDIAN PORCUPINE *HYSTRIX INDICA* IN THE WILD AT JODHPUR, RAJASTHAN

Old World porcupines are the most spectacular rodents and are the most easily recognisable. Their bodies and tails are covered with stiff spines and quills of varying length, and with tough and flexible bristles. Various members of the family are widely distributed over parts of Europe, most of Africa, and Southeast Asia. They live in a wide range of habitats like deserts, grasslands, open scrub, Dry Deciduous and Deciduous Forests, and near crop fields.

In India, the Indian porcupine *Hystrix indica* is distributed from the Himalaya to Cape Comorin (now Kanya Kumari) in Tamil Nadu (Prater 1980). In Rajasthan, it is found in the Aravalli Hills and to their southeast. The present observations were made around Jodhpur city (26° 18' N, 73° 01' E), situated on the eastern fringe of the Great Thar Desert. The rocky habitat used by porcupines in and around Jodhpur city, includes open scrub forest, fields, farms and orchards. During a regular trek towards Bhuteshwar Forest block outside the city walls for the census of the Hanuman langur (*Semnopithecus entellus*) on June 7, 2001 at 0615 hrs, I saw a pack of seven dogs *Canis familiaris* chasing a porcupine near Bharun Temple. The porcupine looked weak and injured. A few drops of fresh blood were also seen on the rocks nearby. The porcupine was moving slowly with erect spines. All seven dogs surrounded it at 2 to 3 m distance and barked. The dogs attacked the porcupine from different sides, snapping at the forelegs about 4-5 times. They also bit at the throat of the porcupine and knocked it down. After 20-25 minutes the porcupine's spines collapsed. Suddenly, one dog jumped on the porcupine's throat from the front, stood opposite the porcupine's body and tried to overturn it. Then, two more dogs joined it and they all held the porcupine tightly till it died.

In general, porcupines are reported to be quite fearless of large predators like panthers and tigers (Prater 1980). Dogs successfully predated on a porcupine in this, perhaps, unusual case. In the last few years, dogs are emerging as potential predators on wild animals like chinkara *Gazella bennettii*, blackbuck *Antilope cervicapra*, and langurs in and around Jodhpur city. A study conducted in the Aravalli Hills suggests that *Canis familiaris* is a potential predator of Hanuman langur at Kumbhalgarh Wildlife Sanctuary (Chhangani 2000).

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2. SIGHTING OF THE INDIAN WILD ASS *EQUUS ONAGER* IN RAJASTHAN: A NORTHWARD RANGE EXTENSION

(*With one text-figure and one plate*)

On the hot afternoon of September 24, 2001 while surveying birds in the Rann near Bhawatra, Jalore district, Rajasthan, I noticed tracks of the Indian wild ass *Equus onager*, but did not see any animals. However, a villager of Kookria (a settlement near Bhawatra) reported that he had chased away two animals from his field of pearl millet *Pennisetum typhoides* on September 23, 2001. On the basis of his report, I made a thorough survey of the Rann near Bhawatra. As a result, I discovered two animals *c.* 7 km southwest of Bhawatra on September 25, 2001 (Fig. 1). The pair was very shy, and realising the rarity of the species in Rajasthan, I did not venture close to them and took some record shots from a distance (Plate 1, Fig. 1).

The Indian wild ass is found in "only two isolated populations in southeast Iran and in the Little Rann of Kutch" (Roberts 1997). According to Prater (1980), "Sálim Ali, writing of the wild ass in Cutch, says that their headquarters lie in the Little Rann." The geographical range of the species within Indian limits is the Little Rann of Kutch, in Gujarat, according to Nameer (2000). There is no authentic record of the Indian wild ass from Rajasthan in the recent past. Therefore, this record from Bhawatra in Jalore district of Rajasthan is the first.

The Indian wild ass once "extended from Afghanistan down into Iran and the Rann of Kutch" (Roberts 1997). There are references to Indian wild ass occurring in Rajasthan. "At the turn of the century (*circa* 1900) large herds extended through Rajputana and into Bahawalpur area" (Roberts 1997). Sterndale (1884) wrote that, "ghor-khur is found sparingly in Cutch, Guzerat, Jeysulmeer, and Bikaneer," and, "Bikaneer herd consists at most of about 150 individuals, which frequent an oasis a little elevated above the surrounding desert, and commanding an extensive view around." As late as *circa* 1943, there is an unconfirmed report of one individual having

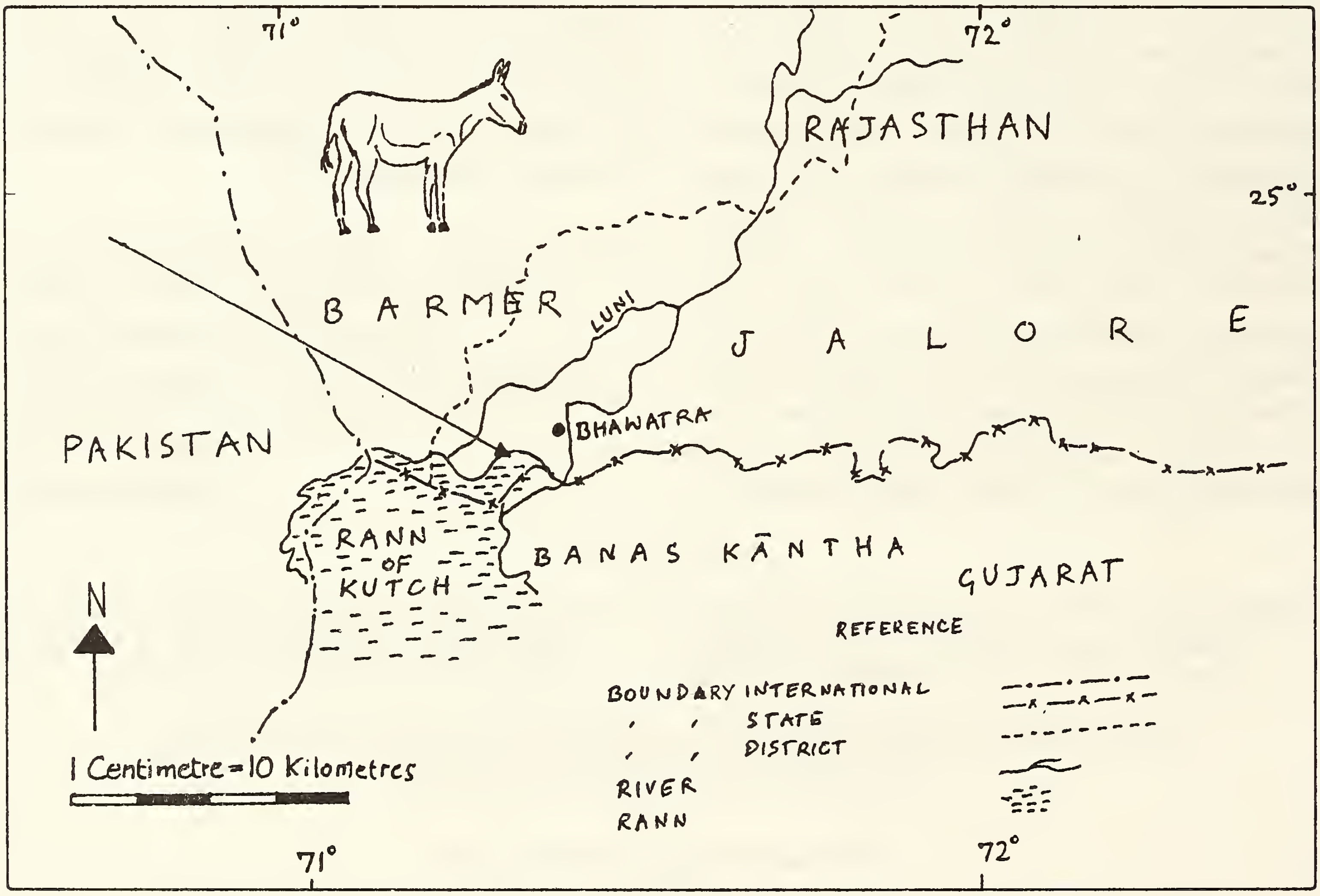

Fig. 1: Map showing new area of Indian wild ass sighting (indicated by arrow) in Rajasthan

Sangha, H.S.: Indian wild ass *Equus onager* PLATE 1

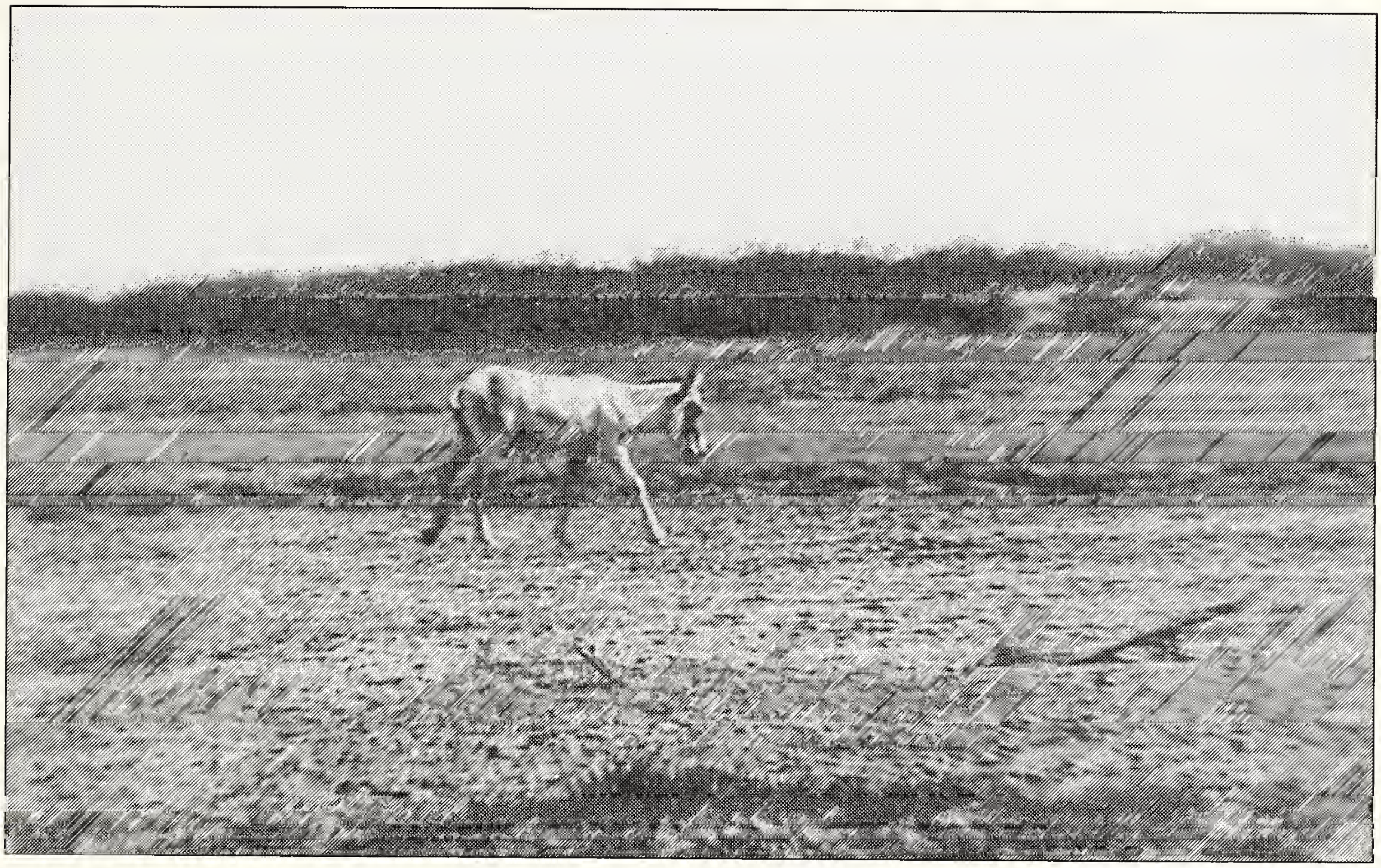

Fig. 1: Indian wild ass near Bhawatra, Jalore district, Rajasthan

strayed in from Bahawalpur (Pakistan) into the former Bikaner State area (Singh 2001).

The sighting of the globally threatened Indian wild ass from Bhawatra, Jalore district in Rajasthan can be attributed to the increase in its population in the Wild Ass Sanctuary in the Little Rann of Kutch during the last two decades. According to Singh *et al.* (1999), the Indian wild ass was restricted to the Sanctuary, and no animal was recorded beyond 5 km from the boundary in 1976. As the population increased, animals started moving away from the boundary. Most likely, the animals which had dispersed earlier to the Great Rann of Kutch from the Little Rann are now spreading further north into Rajasthan along the Pakistan border, as the area between Jalore and the Little Rann is heavily inhabited.

According to Singh *et al.* (1999), the present population of the wild ass in India is about 2,940; it will continue to increase in future and may exceed 4,000 by the year 2010. Therefore, further dispersal in suitable areas in the Rann can be expected in the future. This natural dispersal process may be considered an opportunity by wildlife management authorities to expand existing habitats to the areas that were occupied by the animal in the not so distant past. It is in the interest of conservation of the species to develop the Rann area lying in Jalore and Barmer districts of Rajasthan as an alternative site to the Wild Ass Sanctuary. At present, there is no human activity in this area except for the presence of the Border Security Force (BSF) along the border with Pakistan.

ACKNOWLEDGEMENTS

I would like to thank Prabhsharan Singh Chhina for organising the survey and logistical support, and Divyabhanusinh for references and suggestions.

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3. RING RECOVERY FROM GREAT CORMORANTS *PHALACROCORAX CARBO* IN INDIA

(*With one text-figure*)

While staying at the Forest Rest House of the Pakhui Tiger Reserve at Seijusa in western Arunachal Pradesh during March-April, 1998, and September-October, 1999, I observed great cormorants *Phalacrocorax carbo* in the Pakke river. During the same period, I also had sightings of this species further west near Tipi, in the Kameng or Bhareli river, a tributary of the River Brahmaputra. The cormorants were often observed moving up and down the river in small to large flocks, at times 25-30 birds in a flock. As both these localities occur close to the Assam plains, I thought the cormorants probably moved upstream from roosting areas in the plains to

Arunachal Pradesh for feeding. Little did I know then that these great cormorants included migrants from China.

The great cormorant, *Phalacrocorax carbo* Linn., is the most widely distributed species of Phalacrocoracidae. It is found from the Arctic to the Tropics in both inland and marine waters. One of its subspecies, *P.c. sinensis*, which is known to exhibit the most migratory behaviour (del Hoyo *et al.* 1992), occurs in India. It is seen throughout most of the Subcontinent, being resident and locally migratory, with a regular seasonal influx of extralimital migrants in winter augmenting the resident population (Ali and Ripley 1983, Grimmett *et al.* 1998). There are a few ring recoveries of great cormorants (Fig. 1); birds that had been ringed in Kazakhstan suggest the origin of some of the birds that migrate to India (Abdulali 1976). The following account is the first direct evidence on the migration of great cormorants to India from China. For details of the ring recoveries see Table 1.

In December 1999, Mr. C. Loma, DFO, Pakhui Tiger Reserve at Seijusa in Arunachal Pradesh informed me of a bird ring he had collected from a local hunter and wanted me to ascertain the species and from where it had come. Soon after, in January 2000, while on a visit to Yazali locality in Lower Subansiri district of Arunachal Pradesh,

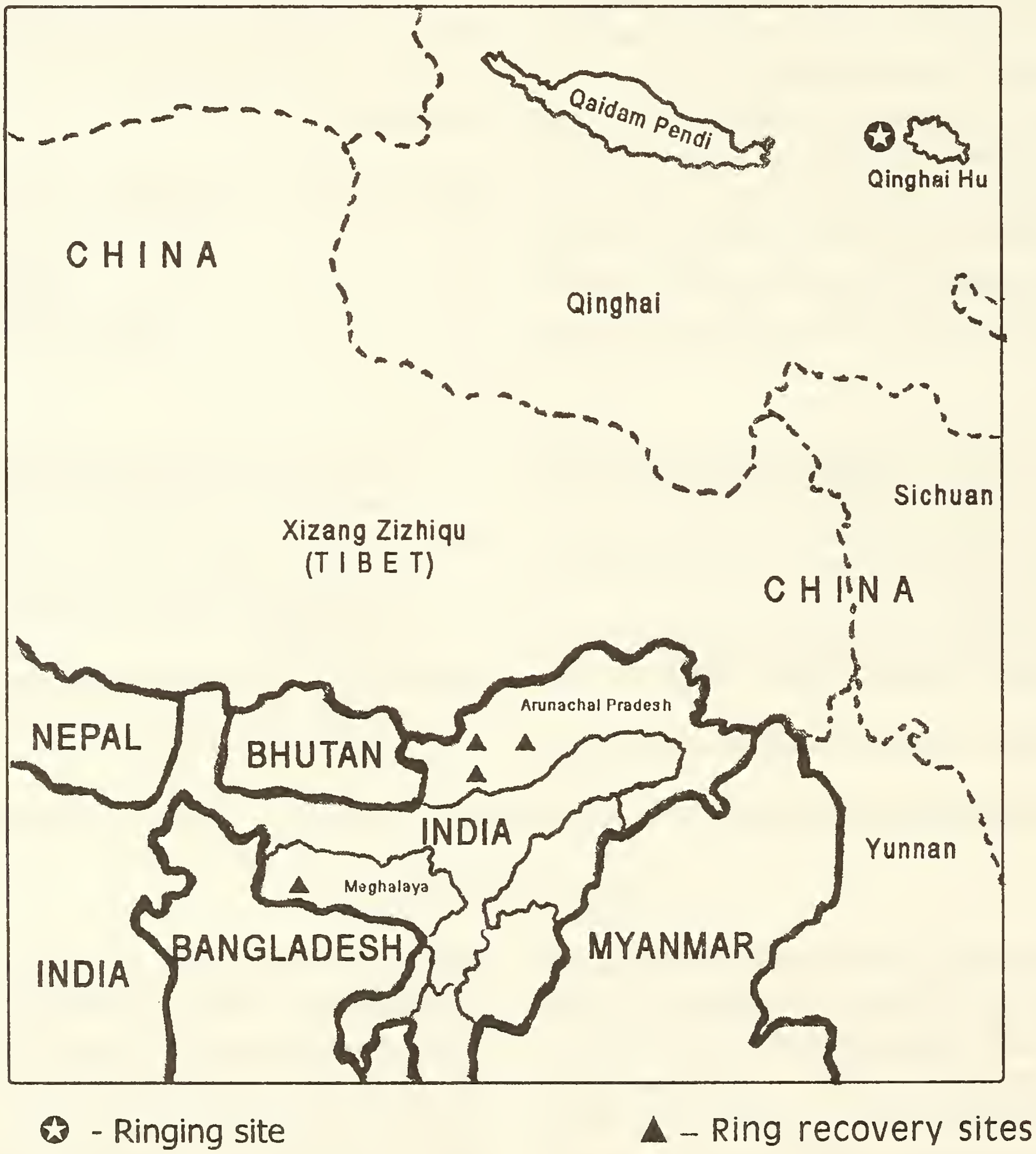
Qaidam Pendi
Qinghai Hu
CHINA
Qinghai
Sichuan
Xizang Zizhiqu
(TIBET)
CHINA
Arunachal Pradesh
NEPAL
BHUTAN
INDIA
Meghalaya
Yunnan
INDIA
BANGLADESH
MYANMAR
✪ - Ringing site
▲ – Ring recovery sites

Fig. 1: Map showing great cormorant ringing and recovery sites

Table 1: Details of ring recoveries in eastern India of great cormorants from China and elsewhere

Ringing details			Recovery details		
Ring No.	Ringing date	Locality, Sex, Age	Recovery date	Locality	Remarks
N00-4541	June 13, 1999	36° 54' N, 99° 54' E Qinghai Hu, Qinghai Province, China. Sex: unclear, Age: nestling	First week of October 1999	*c.* 26° 57' N, 93° 1' E Ranganadhi river (Panior river), Yazali, Lower Subansiri district, Arunachal Pradesh	This ring was collected from a local hunter who had killed the bird for the pot. He reported seeing two birds in the river at the time of shooting.
N00-4947	June 19, 1999	36° 54' N, 99° 54' E Qinghai Hu, Qinghai Province, China. Sex: unclear, Age: nestling	First week of November 1999	*c.* 27° 34' N, 93° 44' E Pakke River, Seijusa (150 m); East Kameng district, Arunachal Pradesh	This ring was also collected from a local hunter who had killed the bird for the pot. The ring was collected by the First Department and shown to me in January 2000. Also a full wing of the bird kept as a trophy was collected.
N00-5013	June 17, 1999	36° 54' N, 99° 54' E Qinghai Hu, Qinghai Province, China. Sex: unclear, Age: nestling	April 3, 2000	*c.* 26° 20' N, 89° 29' E Torsa River, Near Suktabari, Cooch Bihar, West Bengal	This bird was caught alive by a fisherman and after seeing the ring, the bird was handed over to the Forest Department there. After removing the ring, this bird was released on April 5, 2000. (Source: Hillaljyoti Singha and S. Sivakumar, BNHS).
Unknown	-	-	Unknown	Pappu Valley, Seppa, Kameng district, Arunachal Pradesh	A few local people reported seeing cormorants in September in the Pappu Valley and also reported having killed a bird with a ring. This ring, however, could not be located.
Unknown	-	-	Unknown	Garo Hills, Meghalaya	A hunter caught this bird and reported seeing a Russian ring. Unfortunately, the ring has been lost. The exact locality where the bird was caught is not known. (Source: Maan Barua from Kaziranga, Assam)

the Range Forest Officer there also informed me of a bird ring with a local hunter. We later collected the ring, and to our surprise found that the inscription was similar to the one collected in Seijusa, about 300 km away. Enquiry with the hunter yielded no information, except that he had seen two black birds together in the river when the ringed bird was shot.

On returning form Arunachal Pradesh, I learnt from Dr. Taej Mundkur, of Wetlands International – Asia Pacific, that the rings belonged to the National Bird Banding Centre (NBBC) in China. Ms Hou Yunqiu and Mr. Qian Fawen of NBBC were contacted, and they informed me that the rings belonged to great cormorants ringed at Qinghai Hu (Hu = Lake), Qinghai Province (36° 54' N, 99° 54' E), which is about 1,200 km as the crow flies from the localities in Arunachal Pradesh where the rings were recovered.

Further, when the recoveries were reported to the Bombay Natural History Society, I learnt that two researchers, Hillaljyoti Singha and S. Sivakumar had also recovered a ring from a great cormorant on April 3, 2000. A fisherman had caught the bird in the Torsa river near Shuktabari, 17 km from Koch (Cooch) Bihar, West Bengal State. This ring also belonged to the NBBC and the bird was ringed at Qinghai Hu.

The subspecies *P.c. sinensis* is known to occur throughout China, and the northern breeding birds there are reported to winter south of the Yangtze and on Hainan and Taiwan (Meyer De Schauensee 1984). With the ring recoveries of the Qinghai birds, it appears that some populations also winter in India, entering the Subcontinent via the eastern flyway across the Eastern Himalaya. Very little information is available on migration routes in Northeast India, but the Brahmaputra and its tributaries are thought to form a flyway for birds from Northeast Asia (Grimmett *et al.* 1998).

How far these birds move south is not known, but the majority of them could possibly be wintering in the Assam plains. The Kaziranga National Park, a Ramsar site along the river Brahmaputra, supports a large number of migratory birds. Great cormorants are found there throughout the year but the numbers are higher in winter, suggesting a definite migratory supplement (Maan Barua, pers. comm.). It is not clear whether the movement of these Chinese-ringed cormorants is an annual feature, or a dispersal or nomadic movement. Further studies and ring recoveries of great cormorants from the region are required to establish their movements.

August 10, 2001

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4. RECOVERY OF A RINGED DEMOISELLE CRANE *GRUS VIRGO* IN KUTCH

During a routine survey in February, 1999, one of us (MHT) found a dead demoiselle crane, *Grus virgo* Linn., on Ratnal Tank (23° 17' N, 70° 01' E) with the ring number Moskwa B-270 915.

In correspondence with the Moscow Ringing Centre, we came to know that this bird was ringed as a pullet on 23.vii.1989 at Lake Barun-Torey of Russia, Chita O (50° 05' N, 115° 40' E. The bird had travelled 4,917 km and was found dead after 3,115 days (about eight and a half years) in Kutch.

Earlier, Dr. Taej Mundkur had collected a demoiselle crane with a ring at Nyrari Reservoir in Rajkot, Gujarat on February 10, 1992, which had been ringed on 11.vii.1990 near Barun-Torey Lake in Russia (Mundkur 1992).

We thank the Moscow Ringing Centre for providing us with the relevant details.

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5. FIRST RECORD OF LESSER FLORICAN *SYPHEOTIDES INDICA* (MILLER) FROM KEOLADEO NATIONAL PARK, BHARATPUR, RAJASTHAN

A male lesser florican, *Sypheotides indica* in breeding plumage was sighted in the grassland of Keoladeo National Park (27° 7.6' to 27° 12.2' N and 77° 29.5' to 77° 33.2' E), Rajasthan, India, at around 0830 hrs on June 19, 2000.

The bird was identified by its black and white plumage, with a tuft of narrow ribbon-like black feathers behind the head, three on either side. It was sighted in the grassland of Block-G (locally called Koladehar), dominated by two grass species, namely *Vetiveria zizanioides* and *Desmostachya bipinnata*. Koladehar is the major grassland habitat spread over *c.* 3 sq. km in the southeast part of the Park. The grass was green, with an average height of 50 cm. We saw the bird for about half an hour without binoculars, as it was just 15 m away. It could not be located again in the same area during the next two days of intensive search.

The lesser florican breeds during the southwest monsoon, which begins by the end of June or early July in western Gujarat, eastern Rajasthan, western Madhya Pradesh and Andhra Pradesh (Sankaran and Manakadan 1990, Sankaran *et al.* 1992). This is the time when the males return to the breeding grounds. They are known to move from the breeding grounds immediately after nesting, into peninsular India (Ali and Ripley 1983). The dispersal areas are still not known. The bird sighted in the Park could be in transit to the breeding ground and was probably using Keoladeo National Park as a staging ground. The nearest known breeding grounds of the species are more than 300 km southwest of the Park (in Tonk, Ajmer, Bhilwara and Pali districts of Rajasthan). There have been sightings of breeding males in transit towards western India during June, July and August from Karera Bustard Sanctuary in northern Madhya Pradesh where they did not display, and breeding has not yet been recorded from the region (Sankaran *et al.* 1992).

The lesser florican is among the smallest bustards of the world and is endemic to India. Once ranging from Punjab, Rajasthan, Gujarat and Madhya Pradesh in central India to Karnataka, Kerala and Tamil Nadu in the south (Ali and Ripley 1995), it is now restricted to Gujarat, Madhya Pradesh, Rajasthan and Andhra Pradesh. In recent years, the bird has become very rare (Sankaran *et al.* 1992).

As the lesser florican is highly endangered, every sighting is important, and information on dispersal and distribution must be recorded to help in their conservation.

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6. ON THE LONGEVITY OF THE GREAT PIED HORNBILL *BUCEROS BICORNIS* IN CAPTIVITY

Two young female specimens of the great pied hornbill, *Buceros bicornis* Linn., were received at Nandankanan Zoological Park, Bhubaneswar, Orissa on June 26, 1967 through an animal dealer based in Calcutta (=Kolkata). They lived for 32 years, 4 months and 4 days in captivity, and died at an estimated age of 33 years. Both the birds were found dead during the super-cyclone that hit coastal Orissa on October 29-30, 1999.

These hornbills were always displayed in a spacious enclosure encompassing one or more trees, and with provision to protect them from extreme weather conditions. They were fed with goat's meat and liver, banana and boiled rice. Multivitamin supplements were added to the diet intermittently.

The great pied hornbill is uncommon in captivity. It rarely breeds under captive conditions. Sálim Ali (1996) in the BOOK OF INDIAN BIRDS, BNHS/OUP, mentions that the age to which a bird is capable of living varies according to the species, its environment and the particular conditions under which it lives. Perusal of the literature did not reveal any information on the longevity of this species in captivity. The longevity of 32 years, 4 months and 4 days recorded in this Park appears to be the longest so far reported for this species in captivity, though the death was due to unnatural causes.

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7. FORAGING ASSOCIATIONS AND INTERACTIONS IN WOODPECKERS

In the course of my studies on woodpeckers at the Peechi-Vazhani Wildlife Sanctuary, Thrissur district, Kerala, I found that except at the peak of summer, when mixed foraging flocks of birds were less common, woodpeckers were invariably associated with such flocks. In fact, I could locate woodpeckers by looking out for mixed foraging flocks. Up to six, at times even seven, of the eight species of woodpecker in my study sites were seen in a single flock, and often three or four species were seen foraging on the same tree.

Table 1 gives data for two years, showing seasonal variations in the woodpeckers' association with several mixed foraging flocks (as a percentage of total observations). The value in parentheses represents the number of observations. It may be seen from this Table that the woodpeckers' association with mixed foraging flocks declines with the onset of the dry season (summer), and is lowest during the late dry season. Fewer mixed foraging flocks were seen in the dry season, as many constituent species were engaged in nesting in this period. This appeared to result in fewer instances of woodpecker association with the mixed flocks.

In their association with the mixed foraging flocks, woodpeckers were often seen pursued by drongos — greater racket-tailed (*Dicrurus paradiseus*), bronzed (*D. aeneus*) and white-bellied (*D. caerulescens*). Often, the lesser golden-backed woodpeckers *Dinopium benghalense* were followed by racket-tailed drongos that usurped their foraging sites or forced them to give up the insect prey that they had extracted from under the bark of the tree. Most often the drongos succeeded. However, the greater golden-backed woodpecker *Chrysocolaptes lucidus* often stood its ground, and prevented the drongos from kleptoparasitising it.

I have also once seen a racket-tailed drongo displacing a foraging yellow-fronted pied (Mahratta) woodpecker *Dendrocopos mahrattensis* and extracting an insect larva from the site where the latter had been excavating. A brown-capped pygmy woodpecker *Dendrocopos nanus* with an insect in its beak was once seen being chased by the bronzed and white-bellied drongos.

Table 1: Woodpecker association with mixed foraging flocks

Species	Season		
	Late wet (Sept.-Nov.) % (n)	Early dry (Dec.-Feb.) % (n)	Late dry (Mar.-May) % (n)
PY (1991-92)	90.9 (33)	84.2 (38)	23.5 (34)
PY (1992-93)	85.7 (14)	67.6 (34)	30.8 (8)
MA (1991-92)	100.0 (32)	87.2 (39)	25.9 (27)
MA (1992-93)	84.6 (13)	73.5 (34)	21. 4 (14)
HS (1991-92)	72.0 (25)	84.2 (19)	23.1 (13)
HS (1992-93)	83.3 (6)	38.9 (18)	35.0 (20)
YN (1991-92)	90.0 (10)	71.9 (32)	35.3 (17)
YN (1992-93)	100.0 (5)	86.7 (15)	38.5 (13)
RU (1991-92)	76.2 (21)	64.0 (25)	35.3 (17)
RU (1992-93)	100.0 (5)	50.0 (8)	30.8 (13)
GB (1991-92)	85.0 (40)	86.3 (51)	20.7 (39)
GB (1992-93)	94.7 (19)	85.3 (34)	33.3 (24)
MG (1991-92)	65.0 (20)	56.4 (39)	5.3 (19)
MG (1992-93)	50.0 (6)	57.1 (28)	21.7 (23)

PY = *Dendrocopos nanus* (Brown-capped pygmy woodpecker)
MA = *Dendrocopos mahrattensis* (Yellow-fronted pied woodpecker)
HS = *Hemicircus canente* (Heart-spotted woodpecker)
YN = *Picus chlorolophus* (Small yellow-naped woodpecker)
RU = *Celeus brachyurus* (Rufous woodpecker)
GB = *Dinopium benghalense* (Lesser golden-backed woodpecker)
MG = *Chrysocolaptes lucidus* (Greater golden-backed woodpecker)

Apart from associations leading to usurpation of foraging sites or food by drongos, woodpeckers were also followed by birds (including drongos) for insects that were disturbed by them in their process of moving about on the tree trunk or branches. Racket-tailed drongos, red-vented bulbuls *Pycnonotus cafer*, grey-headed starlings *Sturnus malabaricus*, red-whiskered bulbuls *Pycnonotus jocosus* and jungle babblers *Turdoides striatus* were seen following the lesser golden-backed woodpecker *Dinopium benghalense* and little scaly-bellied green woodpecker *Picus xanthopygaeus* foraging on termites, sometimes as close as a metre or so from the woodpeckers. Though the woodpeckers generally never reacted to the presence of these birds, on one occasion I noticed a lesser golden-backed woodpecker lunging at a red-vented bulbul that strayed quite close to it.

Woodpeckers tolerate occasional piracy by the aggressive drongos because of the advantages they enjoy in the form of protection from predators and early warning signals, which they receive from other birds in a mixed foraging flock (Sullivan 1984, Hogstad 1991). I have seen bronzed drongos chasing shikra (*Accipiter badius*) and other raptors that stray within the proximity of mixed flocks.

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8. EXPLOITATION OF SEA TURTLES ALONG THE SOUTHEAST COAST OF TAMIL NADU, INDIA

(*With one text-figure*)

Five species of sea turtles, the leatherback *Dermochelys coriacea*, hawksbill *Eretmochelys imbricata*, olive ridley *Lepidochelys olivacea*, loggerhead *Caretta caretta* and green turtle *Chelonia mydas* occur in the Indian seas. All of them are found along the southeast coast, especially in the Gulf of Mannar (Kar and Bhaskar 1995). Turtle fishing was practised in this region for ages, and chelonians were exported to Sri Lanka and other countries until a couple of decades ago (Agastheesapillai and Thiagarajan 1979, Frazier 1980). In the present paper, we report the exploitation and some aspects of the ethnozoology of sea turtles along the southeast coast of Tamil Nadu, India. We surveyed most of the coastal villages covering the entire southeast coast (*c.* 250 km; Fig. 1), from Cape Comorin (now Kanya Kumari; 8° 4' 40" N, 77° 33' 4" E) to Dhanushkodi (9° 9' 9" N, 79° 26' 46" E) during November 2001. We interviewed the fishermen for information on the occurrence of turtles, their common names and exploitation by locals. Village markets and garbage dumps were also checked for live turtles or shells to quantify the exploitation.

Altogether, we surveyed 29 localities, and obtained 48 cases of sea turtle exploitation in 13 localities. This includes all species except the loggerhead. About 94% of the turtles exploited

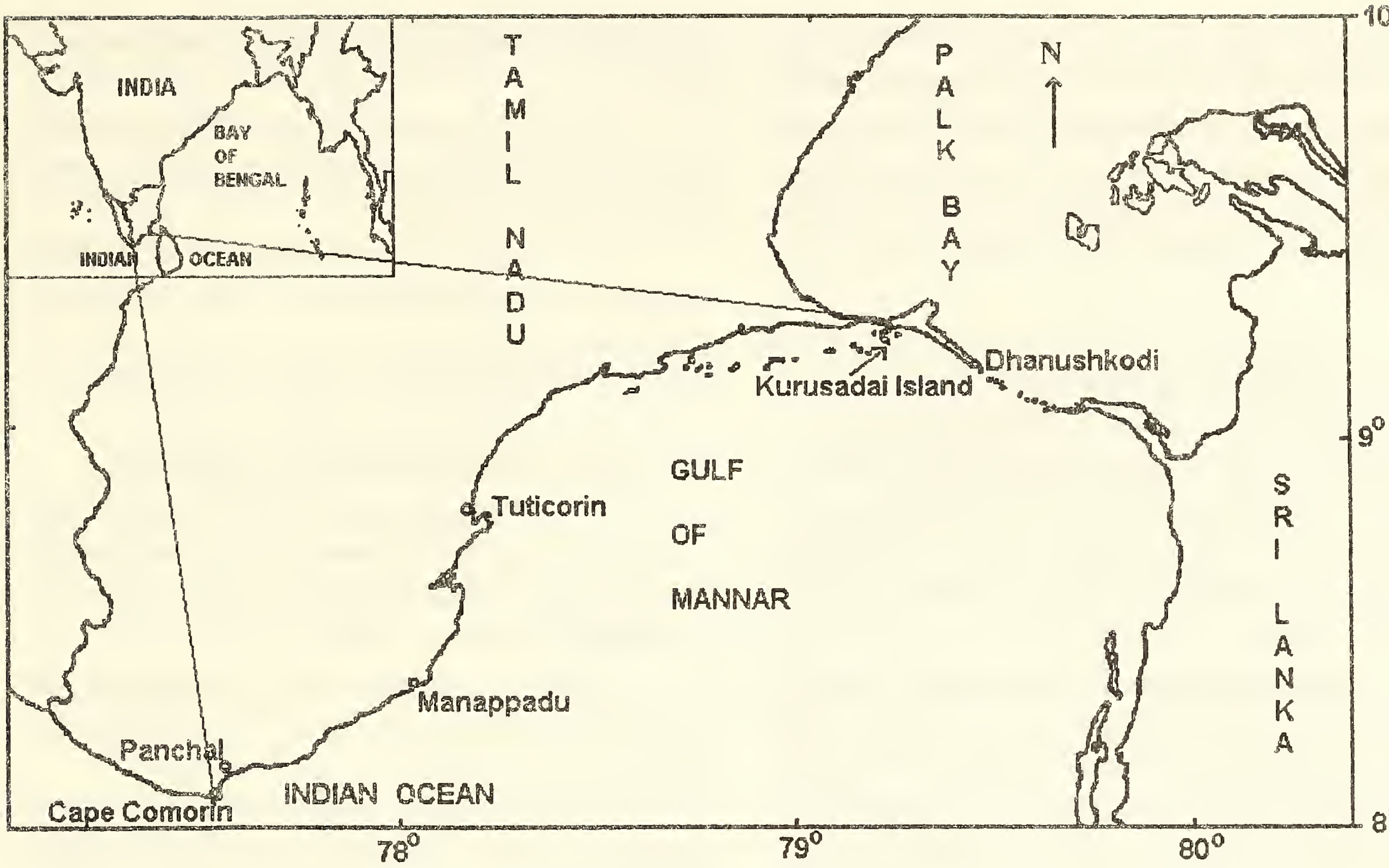

Fig. 1: Map showing the southeastern coast of Tamil Nadu, India

were olive ridleys (47.9%) and green turtles (45.8%). Agastheesapillai and Thiagarajan (1979) reported that the green turtle formed *c.* 89% of all turtles caught in the Gulf of Mannar and Palk Bay during 1971-76. However, the present study shows that the proportion of green turtles caught declined from *c.* 90% to 46%, while on the other hand, the olive ridley increased substantially from <10% to 48%. The reduction in the green turtle catch could be due to overexploitation in the past. Before 1950, other species were seldom consumed (Kuriyan 1950). This indicates that the green turtle has been depleted beyond sustainable level, and the locals are forced to utilise other species such as the olive ridley. Local fishermen reported that they would prefer the green turtle to other species for food. The green turtle is known as "theen aamai" (theen = honey, aamai = turtle) in this part of the country, indicating a preference for this species. Turtle meat price ranged from Rs. 75-150 per kg, and the eggs were priced at Rs. 0.75-2.00 per egg. It is believed that turtle egg, meat and blood cure diseases such as tuberculosis and piles.

Other species such as the leatherback turtle were exploited on availability. According to Das (1995), the leatherback becomes poisonous during certain seasons along the southern coast of Sri Lanka. However, the species most dreaded by the locals on the southeastern coast of India is the hawksbill turtle, and is not consumed due to the poisonous nature of its meat (Das 1995). As reported by Kar and Bhaskar (1995), the villagers still remember the death of 9 persons in 1979 after consuming the hawksbill in Manapaddu near Tuticorin.

Various uses of the sea turtles are given in Das (1995). Oil extracted from the leatherback is used for boat maintenance. Hawksbill shell is preserved for the tortoiseshell industry. In certain villages, the carapace of the olive ridley and green turtle is used as a container during dyeing of boat sails. The dye is obtained from crushed tamarind husk and seeds. According to the elderly fishermen, the fat remaining in the shell acts as a fixative. Until a few years ago, this practice was common along the coast. Now, plastic containers and synthetic dyes have replaced the turtle shell.

It appears that the current exploitation of sea turtles in southeastern Tamil Nadu is for subsistence, and fishermen do not go exclusively for hunting sea turtles. However, turtles entangled in the net, and remaining alive, are taken for consumption. Turtles usually get caught in ray fish nets, locally known as 'tirukku valai' (tirukkai = ray fish, valai = net). This is a type of gillnet similar to the 'pachu valai' described by Kuriyan (1950). The length and width of the nets commonly used in the region are 54 m and 6 m respectively. The net is made up of multifilament polymer, and the mesh size varies from 15 to 22 cm. Fishermen reported that six olive ridleys got entangled in a net (324 sq. m) spread for about 10 hrs during mid-November 2000.

All species of turtle are known as 'aamai' in the local language, Tamil. The residents of this area are aware of the occurrence of at least four species of sea turtles, and identify them largely by colour, size and general appearance. Each species has more than one local name, as given below.

Olive ridley sea turtle *Lepidochelys olivacea*

i. Yeth aamai: Yeth = that comes up; the turtle that comes up, and is often found nesting.

ii. Panchal aamai: Panchal is a coastal village near Kanya Kumari, where this species is reportedly common.

iii. Vakkatta aamai: Vakkatta = poor; the turtle yields little meat compared to other species, and is the smallest marine turtle in the region.

Green turtle *Chelonia mydas*

i. Peruthalai/Perunthalai aamai: Peruthalai/perunthalai = largeheaded; the turtle with a large head.

ii. Theen aamai: Theen = honey; locals report that the meat of this species tastes good, and they relish eating it.

iii. Panguni aamai: Panguni is a Tamil calendar month (≈March-April), when this turtle is commonly seen.

iv. Per aamai: Per = big; large turtle.

Hawksbill turtle *Eretmochelys imbricata*

i. Yeli/Yelithalai aamai: Yeli = rat, yelithalai = rat head; the turtle whose head resembles a rodent's head — the upper jaw of the turtle is curved like that of a rodent.

ii. Alungu aamai: Alungu = pangolin; the turtle with overlapping scutes like the pangolin *Manis crassicaudata*.

iii. Kili mookku aamai: Kili = parakeet, mookku = beak; the turtle with a curved upper jaw like the beak of a parrot or parakeet.

Leatherback turtle *Dermochelys coriacea*

i. Panni aamai: Panni = pig; turtle that resembles a pig, perhaps due to its size and colour.

ii. Oongal aamai: Oongal = dolphin; the turtle that looks like a dolphin.

iii. Ezhuvari aamai: Ezhu = seven, vari = line or keel; the turtle that has seven lines or keels on the shell.

iv. Ooduvetti aamai: Oodu = run, vetti = cut; according to the locals, when this species is moving, its strong flippers can injure the person disturbing or handling it.

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9. RECORD OF THE PAINTED KALOULA *KALOULA TAPROBANICA* IN ANDHRA PRADESH

The painted kaloula, *Kaloula taprobanica* Parker, is a medium sized (5.0-8.0 cm) frog that prefers urban areas and open forests (Daniels 1997). The species is reported from Assam, West Bengal, Bihar, Madhya Pradesh, Orissa, Karnataka and Tamil Nadu (Dutta 1997). The species has not been reported from Andhra Pradesh, though reported from its four bordering states (Orissa and Madhya Pradesh in the north, Karnataka to the west and Tamil Nadu to the south) (Daniel 2002, Dutta 1997).

During our studies on the herpetofauna in Sriharikota Island, Nellore district, Andhra Pradesh, we found the species to be one of the most common frogs on the Island. Sriharikota borders Tamil Nadu, and records of the species in this State are from its eastern areas (Daniels 1997). Specimens have also been collected from the suburbs of Chennai (Tambaram) in 1966 (Giri *et al.* 2001) *c.* 80 km south of Sriharikota. Though close to Chennai, our record of the species in Sriharikota deserves attention, as the species has not been recorded from Andhra Pradesh. Additionally, the record is significant due to the insular nature of the landmass, with the Bay of Bengal to the east and Pulicat Lake on its northern, eastern and southern borders. There is also a possibility of the species occurring in other coastal areas to the north of Sriharikota in Andhra Pradesh.

A voucher specimen has been deposited in the BNHS Collection, Regn No. BNHS 4190.

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10. PREDATION OF DRAGONFLY *ICTINOGOMPHUS RAPAX* (RAMBUR) (ODONATA: ANISOPTERA) BY ROBBERFLY *STENOPOGON PRADHANI* JOSEPH & PARUI (DIPTERA: ASILIDAE)

While on a faunistic survey in Sanjay Gandhi National Park (SGNP), Mumbai, at around 1000 hrs, on March 20, 2001, we observed a dragonfly being chased by a robberfly at a height of at least one metre above the ground, in the vicinity of the BNHS Conservation Education Centre, Goregaon. After a brief chase, the robberfly succeeded in catching the odonate by its neck, and within moments, the prey, along with the predator, fell to the ground. By this time, the prey was moribund. We collected both the specimens and identified the prey as *Ictinogomphus rapax*, a dragonfly, and the predator as *Stenopogon pradhani*, a robberfly. The strength of the robberfly, considering the comparative size of the prey, was amazing.

Robberflies are well known aerial hunters, and are known to be agile in capturing prey. Birds, lizards, fishes, frogs and spiders are among the best known predators of dragonflies. Birds take a heavy toll on these insects during their emergence, when their weak flight makes them easy prey. Fishes and frogs feed on larvae and early imaginal stages of dragonflies (Fraser 1933).

Several workers in the past have recorded the predation of dragonflies by spiders, from different parts of the country (Kumar and Prasad 1977, Ram and Prasad 1978, Mitra 1994, Kulkarni *et al.* 1999).

Robberflies are known to prey chiefly on Hymenoptera, Diptera, Coleoptera and Lepidoptera, and less frequently on Orthoptera, Neuroptera, Hemiptera and Odonata.

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11. CONGREGATIONS OF COMMON CROW BUTTERFLIES *EUPLOEA CORE* CRAMER AT ARALAM WILDLIFE SANCTUARY, KERALA

Males of many Danaine butterflies are known to be attracted to the withered or damaged parts of plants belonging to Family Asteraceae, Papilionaceae, and Boraginaceae. They usually apply a fluid by means of the proboscis, and reimbibe the fluid along with the dissolved pyrrolizidine alkaloids (PAs), which are used as male pheromone precursors and as protective chemicals.

Barnes (1939) recorded the attraction of Danaine butterflies to *Cynoglossum denticulatum* (Boraginaceae) at Biligirirangan Hills, Karnataka. Wynter-Blyth (1957) recorded Danaine butterflies attracted to *Crotalaria* in south India and to thistles in the Himalaya. Subsequently, plants like *Heliotropium indicum* (Boraginaceae) (Amladi 1975) and *Crotalaria retusa* (Papilionaceae) (Chaturvedi and Satheesan 1979) were recorded as attractants. Larsen (1986b) observed Danaine butterflies attracted to *Ageratum conyzoides* (Asteraceae) at New Delhi. Later, Haribal (1992) noted these insects being attracted to *Paracaryum coelistinum* (Boraginaceae), and Chaturvedi (1994) observed them on *Trichodesma indicum* (Boraginaceae). Jafer Palot *et al.* (1997) reported an aggregation of these butterflies on *Crotalaria peduncularis* and *Heliotropium indicum* in the Periyar Tiger Reserve, Kerala. Karthikeyan (1999) reported a congregation of Common Crows on the dry roots of *Chromolaena odorata* (Asteraceae) at Bannerghatta National Park, Karnataka. Larsen (1986a) observed an aggregation of Danaine butterflies at Corbett National Park, and Jafer Palot (2000) reported an aggregation of these butterflies at the Nehru Zoological Park, Hyderabad. Both the latter were dry season aggregations and are not connected with pyrrolizidine alkaloids.

Aralam Wildlife Sanctuary is 75 km away from Kannur city and is situated in the southern Western Ghats, located between 11° 49' - 11° 50' N and 75° 49' - 75° 57' E. During a stay at the Sanctuary from February to April 2001, I recorded these observations at Narikadavu (100 m above msl), on the banks of the River Cheenkannipuzha, which is the major river in the Sanctuary. Narikadavu is *c.* 14 km east of the Asst Wildlife Warden's Office at Valayamchal.

On March 15, 2001, at 0830 hrs (28 °C, 42% RH) I saw a large tree that had fallen into the river, partially submerged, with exposed and withered roots on the shore. On the roots there were, in congregation, approximately 13 Common Crow *Euploea core* Cramer butterflies and a Blue Tiger butterfly *Tirumala limniace* Cramer. The tree was identified as *Hopea parviflora* Bedd. (Dipterocarpaceae). The butterflies seemed to rub their proboscids against the withered roots and appeared to be imbibing some substances, possibly alkaloids, from these exposed and withered roots.

The next day at 0930 hrs, I observed 14 Common Crow butterflies at the same spot on the tree. On March 17, at 0900 hrs, I saw about 12 Common Crow. By 0930 hrs, the number increased to 20 (28 °C, 46.5% RH). All seemed to be imbibing material from the exposed and withered roots of the tree. At 1030 hrs (29.5 °C, 35% RH) a Blue Tiger butterfly also appeared. While the temperature rose progressively, the butterflies began to leave, and by 1130 hrs (32.5 °C, 19% RH) there were none. On the previous days, at 1300 hrs, no butterflies were seen at the site.

On March 18, at 0800 hrs, I observed 25 Common Crows and a Blue Tiger at the same site. After 2 days, no butterfly congregation was seen. The congregation and imbibing of substances was observed in the morning, mainly before 1130 hrs. In this particular area, Dark Blue Tiger *Tirumala septentrionis* Butler were abundant, and some were seen mud puddling nearby. But not a single Dark Blue Tiger participated in the congregation.

ACKNOWLEDGEMENTS

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12. OBSERVATIONS ON THE ECOLOGY OF RAFT SPIDERS (ARANEAE: PISAURIDAE) IN MADHYA PRADESH

The majority of spiders are terrestrial in habit, but those belonging to the genus *Dolomedes*, commonly known as raft spiders, are exceptional. These spiders are of semi-aquatic habit, and are found only in aquatic habitats near the edges of ponds and marshes (Levi and Levi 1968). These spiders are called raft spiders, due to the erroneous belief that they construct rafts. They are classified under Family Pisauridae, which is closely related to Family Lycosidae, the wolf spiders.

In December 2001, while collecting insects and spiders near the bank of a large water body called Dudhiya Talab along the Jabalpur-Nagpur Highway in Seoni district, Madhya Pradesh, some interesting brownish green spiders were noticed scurrying around the rotting leaves, vegetation and algal bloom at the edge of the water body. At first glance, they appeared like wolf spiders, but on closer inspection, they were identified as raft spiders. On recognising these rare and unusual spiders, their behaviour was closely observed.

The spiders were medium sized (*c.* 10 mm long) and were mostly observed sitting on floating leaves, twigs and rotting vegetation near the edge of the pond, with 3 pairs of posterior legs on the substratum and one pair of front legs spread out, touching the water and waiting patiently to detect a prey. Whenever a spider felt threatened by the author, it would run forward rapidly on the surface of the water, just like a water strider, and sit on a floating leaf about 2-3 m away from the edge of the pond. On many occasions, when an attempt was made to catch a spider, it would run forward and go underwater, clinging to the surface of a leaf or any other object floating in the water. Each spider thus hiding, emerged cautiously a few minutes later. Many wolf spiders (Family Lycosidae) were also present near the edge of the same pond, revealing that they were the main competitors of raft spiders in the habitat. The raft spiders could not be observed catching prey, so a few specimens were caught with the help of a sweep net and kept alive in some vials. They were given some aquatic hemipteran bugs collected from the same habitat. The spiders readily fed on these bugs. Later on, the collected spiders were preserved in 70% ethyl alcohol and deposited in the Collection of the Zoological Survey of India, Jabalpur, Madhya Pradesh.

A review of the literature reveals that there is no previous record of *Dolomedes* spiders or of the Family Pisauridae from Madhya Pradesh. These spiders feed mainly on terrestrial and aquatic insects found in their habitat, but there have also been reports of them catching small fish and tadpoles (Gertsch 1979, Mafham and Mafham 1983, Kumar *et al.* 1999). As a result, these spiders are also known as fishing spiders. They can also remain underwater for considerable periods. Gertsch (1979) has reported them remaining under water for 45 minutes at a stretch. Kumar *et al.* (1999) have reported *Dolomedes fimbriatus* remaining under water, clinging to the roots of the aquatic plant *Pistia* for a maximum duration of five and a half hours. They suggest that the spider's body hairs retain air bubbles that make contact with the respiratory orifices, and may thus provide the oxygen required for breathing under water.

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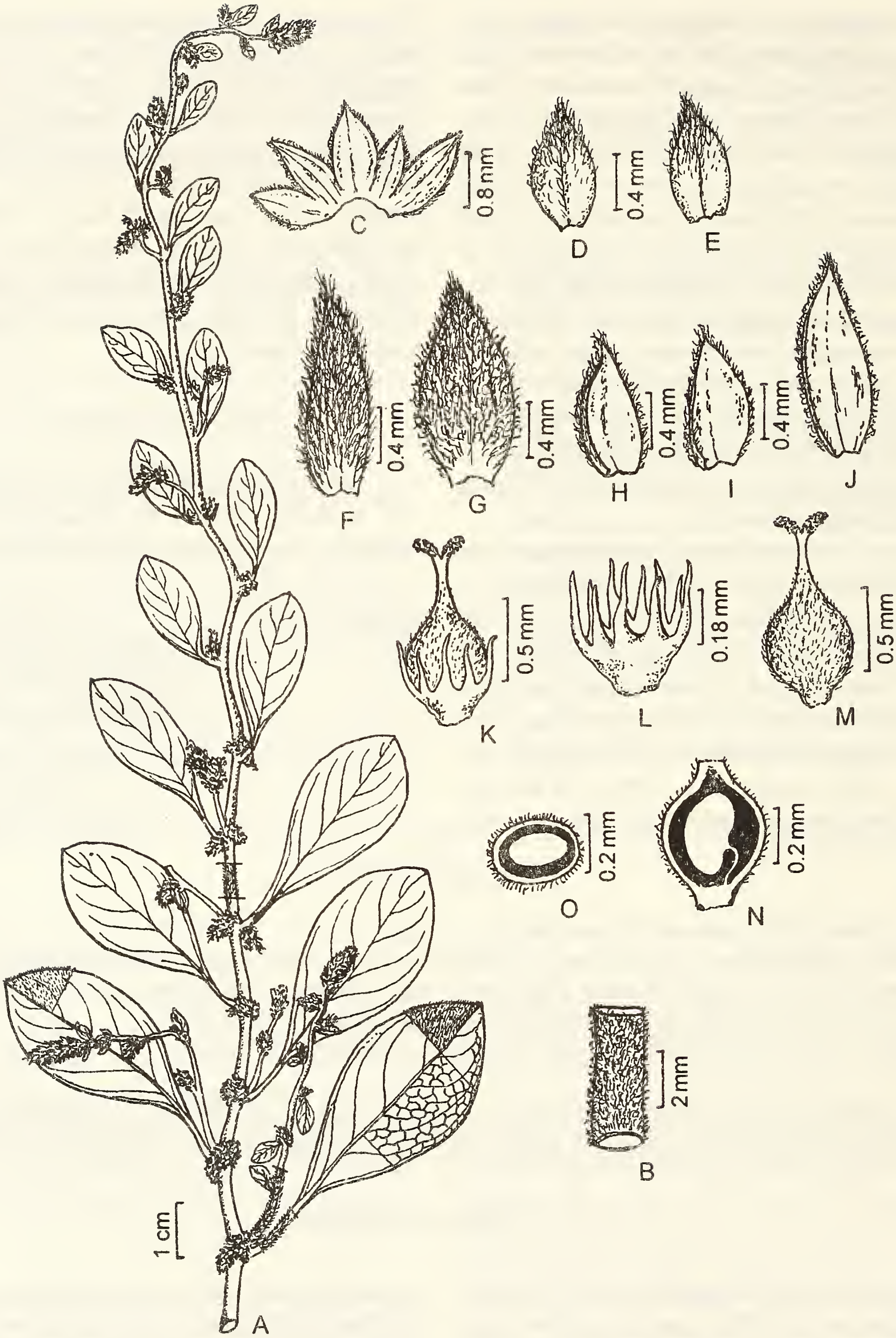
13. REDISCOVERY OF *AERVA WIGHTII* HOOK. F. (AMARANTHACEAE), AN ENDEMIC, PRESUMED EXTINCT SPECIES, FROM TIRUNELVELI DISTRICT, TAMIL NADU, INDIA

(*With one text-figure*)

J.D. Hooker described *Aerva wightii*, Amaranthaceae, in 1885, based on a collection by Robert Wight from Courtallum, Tirunelveli district, Tamil Nadu, India. Gamble collected it in September 1914 from a different locality, Naterikal, in the same district. Ahmedullah and Nayar (1987) treated it as an endemic to this district. Bhattacharyya and Haldar (1990) stated its survival as indeterminate and suggested locating populations in the natural habitat for introduction in botanic gardens for conservation and study. Nayar (1996) doubted its presence in nature, assigned it extinct category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M
0.5 mm
O
0.2 mm
N
0.2 mm
B
2 mm
1 cm
A

Fig. 1: *Aerva wightii*; A. A twig; B. Part of stem, enlarged; C. Perianth; D. Bracts; F - J. Tepals; K. Hypogynous cup and ovary; L. Hypogynous cup; M. Ovary; N. Ovary (l.s.); and O. Ovary (c.s.)

based on general field studies, and recommended a fresh survey in the type locality. After a lapse of about 85 years, it was rediscovered in the locality Puliyangudi Reserve Forest of the same district in January 1999 and is being represented here with a detailed description and an illustration.

Aerva wightii Hook. f., Fl. Brit. India 4: 728. 1885; Gamble, Fl. Pres. Madras 1178. 1925 (2: 825.1957 repr. ed.); Ahmedullah & Nayar, Endemic Plants Indian Region 1: 71. 1987; Kumari in Henry, Kumari & Chithra, Fl. Tamil Nadu 2: 190. 1987; Bhattacharyya & Geeta Haldar in Nayar & Sastry, Red Data Book Indian Plants 3: 11. 1990; Nayar in Molur & Walker, C.A.M.P. Report II: 59. 1996.

Sub-shrubs, arising from a woody rootstock, scandent below, erect above, up to 35 cm high; branches profuse, stiff. Leaves alternate, orbicular or obovate, 1.5-6.8 x 0.5-2.7 cm, attenuately cuneate at base, entire at margin, obtuse at apex, sparsely pubescent above, densely tomentose beneath, petioles up to 1.5 cm long. Spikes axillary, sessile, in clusters, yellowish white, densely woolly, up to 2.7 cm long; bracts unequal, hyaline, oblong-obovate, *c.* 1.8 x 0.4 mm, cuneately truncate at base, entire at margin, mucronate at apex, woolly outside, glabrous inside. Tepals 5, dissimilar, hyaline; 3 more or less similar, elliptic-ovate, 1.2-1.4 x 0.6-0.8 mm, acute at base, entire at margin, 1 acuminate at apex, another 2 mucronate at apex, woolly outside, glabrous inside; 2 oblong-elliptic, 1.6-1.8 x 0.5-0.6 mm, cuneately truncate at base, entire at margin, mucronate at apex, woolly outside, glabrous inside. Stamens 5; filaments subequal, *c.* 0.4 x 0.4 mm, connate in a hypogynous cup; staminodes 5, subulate, *c.* 0.4 x 0.4 mm, flattened towards base. Ovary globose, *c.* 0.5 x 0.5 mm, glabrous, button-like at base; style subulate, *c.* 0.5 x 0.2 mm, glabrous; stigma 2-fid, subulate, *c.* 0.2 x 0.12 mm.

Distribution: Tirunelveli district, Tamil Nadu, India.

Material examined: Tirunelveli district: Courtallum, Southern Herbarium, Robert Wight 42325 (MH, Acc. No.); Naterikal, 23.ix.1914, J.S. Gamble 10982 (MH); Pulmottai, Puliyangudi R.F., 22.i.1999, *c.* 950 m, M.B. Viswanathan & N. Ramesh 1082 (Sri Paramakalyani Centre for Environmental Sciences, Manonmaniam Sundaranar University, Alwarkurichi).

Habitat: High altitudinal grassland dominated by *Cymbopogon flexuosus* with sparse occurrence of trees such as *Phyllanthus emblica*, *Pterocarpus marsupium* and *Bridelia crenulata*, herbs like *Plectranthus amboinicus* and *Anisomeles malabarica* and *Pterolobium hexapetalum* which is described as an 'armed straggler.'

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14. ETHNOBOTANICAL STUDY AND *EX SITU* CONSERVATION OF *ALPINIA GALANGA* WILLD. — A PROMISING MEDICINAL PLANT

Ethnobotany deals with studies among tribal and indigenous peoples to record their knowledge of plant wealth, and to find new resources of herbal drugs, edible and other useful plants. It also includes the attitudes and impact of human beings on plants in their vicinity. For centuries, indigenous people have managed their ecosystems for sustainable as well as for medico-pharmaceutical purposes. Such studies necessitate an understanding of the strategies employed to grow and harvest plants, and of the distribution of medicinal taxa along the land use types in and around a community.

According to the World Health Organization, an estimated 3.5 billion people in the developing world depend on plants for primary healthcare (Balick and Cox 1996); 85% of the traditional medicines in primary healthcare are derived from plants (Balick *et al.* 2000) and nearly 75% of the drugs mentioned in various pharmacopoeia are growing in India. Many people rely on medicinal plants because of their effectiveness, a lack of modern medical alternatives and traditional cultural preference. Ethnobotanical studies acquired priority because knowledge of native populations and their environment was threatened, while ethno-medical uses are documented for only *c.* 28% of plants on earth (Akerele 1991, Rossato *et al.* 1999).

India has an ancient, rich and diverse living tradition in the use of medicinal plants. Northeast India possesses great biological and cultural diversity, and the selection and domestication of plants for use in herbal medicine is ongoing.

Alpinia galanga, commonly known as Greater Galanga (English), Kulanjan (Hindi, Sanskrit), or Kanghu (Manipuri), grows wild in the Manipur Hills. It is a little known, rare, herbaceous perennial of the family Zingiberaceae and is a native of Indonesia, Malaysia and India, mainly in the Eastern Himalaya and parts of southwest India. The rhizomes contain an oil, also called galanga oil, which has great medicinal value. The seeds are also used in medicine.

Conservation of this plant would benefit both the ecological integrity and cultural heritage of the region, and may provide a useful model for other sites. The objectives of the present study were: (i) to quantify and document the use of *A. galanga* in traditional medicine, and (ii) to develop sustainable management practices for its conservation in the field.

Alpinia galanga Willd. germplasm was collected from various places in Northeast India. Data and herbarium specimens were also collected. Surveys were made in 1999-2001 and open-ended interviews conducted with practitioners (herbalists, midwives, elders), and local people concerning plant use. Information was obtained from farmers, community members and curio sellers. We observed the use of plant parts in several tribal villages, and displays at roadside stalls.

A standard exploration schedule was designed with the help of language translators who assisted during the trip. Collections of germplasm were made with the help of local tribals and others, and the material was identified and confirmed with help from the Botanical Survey of India.

RESULTS

Field surveys for *Alpinia galanga* in 1999-2000 revealed that this plant grows wild only around Imphal, Mao and Maran areas, Ukrul and adjoining areas, and around Laithang in Manipur. It was also found growing in tribal kitchen gardens. Field trips during 2000-2001 were, therefore, confined to these regions.

Ethnographic background

Manipur is the easternmost state in the northeastern hill region of India at 51 m to 2,500 m above msl. Almost one-tenth of the area is covered by valleys, and the rest, hills. This temperate to subalpine area is inhabited mainly by Kuki, Tangkhul, Rongmai, Naga, Paite, Marh, Mao, Maran and Thangal tribals. Often, within small contiguous areas, there live many tribal communities, which differ markedly in socioeconomic and cultural values, isolated by language, cultural barriers and poor communication due to the difficult hilly terrain. The remote tribal areas have practically no organised medical facility. The high cost of antibiotics, pharmaceuticals and specialised healthcare enforces local dependence on traditional medicine.

The only difficulty in this work was that the tribals do not disclose easily the secret of the plants they use for medicinal and other purposes. They believe that the curative properties of the plant would be lost if they do so. They disclose these secrets only to their kith and kin, and that too, when they are near death. Much patience was required to win the confidence of the people to collect data.

Botanical description

Root: Perennial, tuberous, slightly aromatic, deep orange-brown, pungent, bitter. Rhizomes: Slightly aromatic like ginger, reddish brown, internally reddish white. Stem: Pseudostem, elongated, 200-250 cm. Leaves: 30-40 cm x 10-15 cm, green, glossy on both sides, oblong, short-stalked, lanceolate, smooth. Inflorescence: Panicles copiously compound, branched, densely flowered, 15-30 cm long, rachis densely pubescent, and branches short. Flowers: About 3 cm long, greenish white, in compound dense bunches, pedicles 0.8-1.25 cm, bracts small, ovate, flowers small. Calyx: Greenish white, 1.25 cm, oblique at the throat, smooth, one-toothed. Corolla: Segments 0.8-1.25 cm, lip distinctly clawed, 5-6 cm, basal glands ascending, white striated with red, linear subulated, exterior limb of corolla with 3 subequal recurved divisions, interior one unguiculate, oval, deeply bilobed. Stamens: Arcuate, shorter than tip. Ovules: 1-2 in a cell. Fruits: Orange red, 1.25 cm long, obovate, smooth. Seed: Globose or angled, much compressed, deep chestnut coloured, a little wrinkled, arillate except at the apex.

Phenology: F. April to June; Fr. November to December.

Propagation: Wild populations of *Alpinia galanga* Willd. reproduce vegetatively through rhizomes.

Distribution: Native to Indonesia, Malaysia and India, mainly in the eastern Himalaya, Western Ghats and southwest India.

Utilisation by Manipuri tribals

The faintly aromatic, pungent and somewhat bitter tubers are used as a substitute for ginger. *A. galanga* rhizomes are ground, and used in their normal diet. The plant is believed to improve the appetite, and the taste of food. It stimulates blood circulation and has a good taste. It is used in bronchitis, dyspepsia and heart disease. The juice of the rhizomes is used as a disinfectant and freshener. A decoction is taken after childbirth.

It is also variously used as stomachic, aphrodisiac, tonic, diuretic, expectorant, and for rheumatic pain, sore throat, sour eructation, stuttering, chest pain, diabetes, and to alleviate tubercular glands, and diseases of the kidney. Galanga oil, extracted from the rhizomes of the plant, is believed to have antitumor, anti-ulcer, anticaliculi, antibiotic and fungicidal properties.

Seeds are considered calefacient alterative, stomachic, sternutatory, beneficial in colic, diarrhoea and vomiting. Fungal infections on the skin are treated with seed paste, as it contains the fungicidal, diterpene. It is also believed to have cytotoxic properties.

Ex situ conservation and management

Rhizomes of wild plant populations were collected and brought to the experimental farm of NBPGR Regional Station, Barapani. They were divided into small pieces containing 2-3 emerging buds, weighing 60-80 g each. While still fresh, they were planted at a depth of about 5 cm in raised nursery beds, 2.7 m x 2.1 m. Row-to-row distance of the raised beds was 45 cm and plant-to-plant distance within a row was 30 cm. Eighty-four raised beds were made, each containing 42 sample rhizomes, i.e. a total of 3,528 plants were grown in the experimental nursery. The following observations were made on one year old plants:

i) Germination percentage of rhizomes was almost 100%.
ii) Average number of culms per plant was 22.
iii) Average height of the one year old plant was 115 cm.
iv) Average fresh weight of the rhizome per one year old plant was 450 g.
v) Rate of multiplication per plant was 10 per year, i.e. rhizomes from a year old plant yielded 10 pieces for replanting.

Economic potential

Based on the average weight of rhizomes from one year old wild plants in kitchen gardens, and those cultivated, the average yield of the rhizomes was calculated to be around 25 tonnes per hectare. However, extrapolating from one year old plants in the experimental plots and the average weight of the rhizomes, it was estimated to be a potential yield of 35 tonnes per hectare, which may increase on optimising a cultivation package. Dried rhizomes of *A. galanga* were being sold in the local market of Manipur, and also in Delhi. The market price was Rs. 22-25 per kg.

Alpinia galanga Willd. is an easily cultivable potential medicinal plant. If cultivated commercially, it can make a good cash crop. It may be pointed out that development of agrotechniques for the commercial cultivation of this plant will benefit the farming community and other tribals in northeast India and provide them with a source of income.

June 8, 2002

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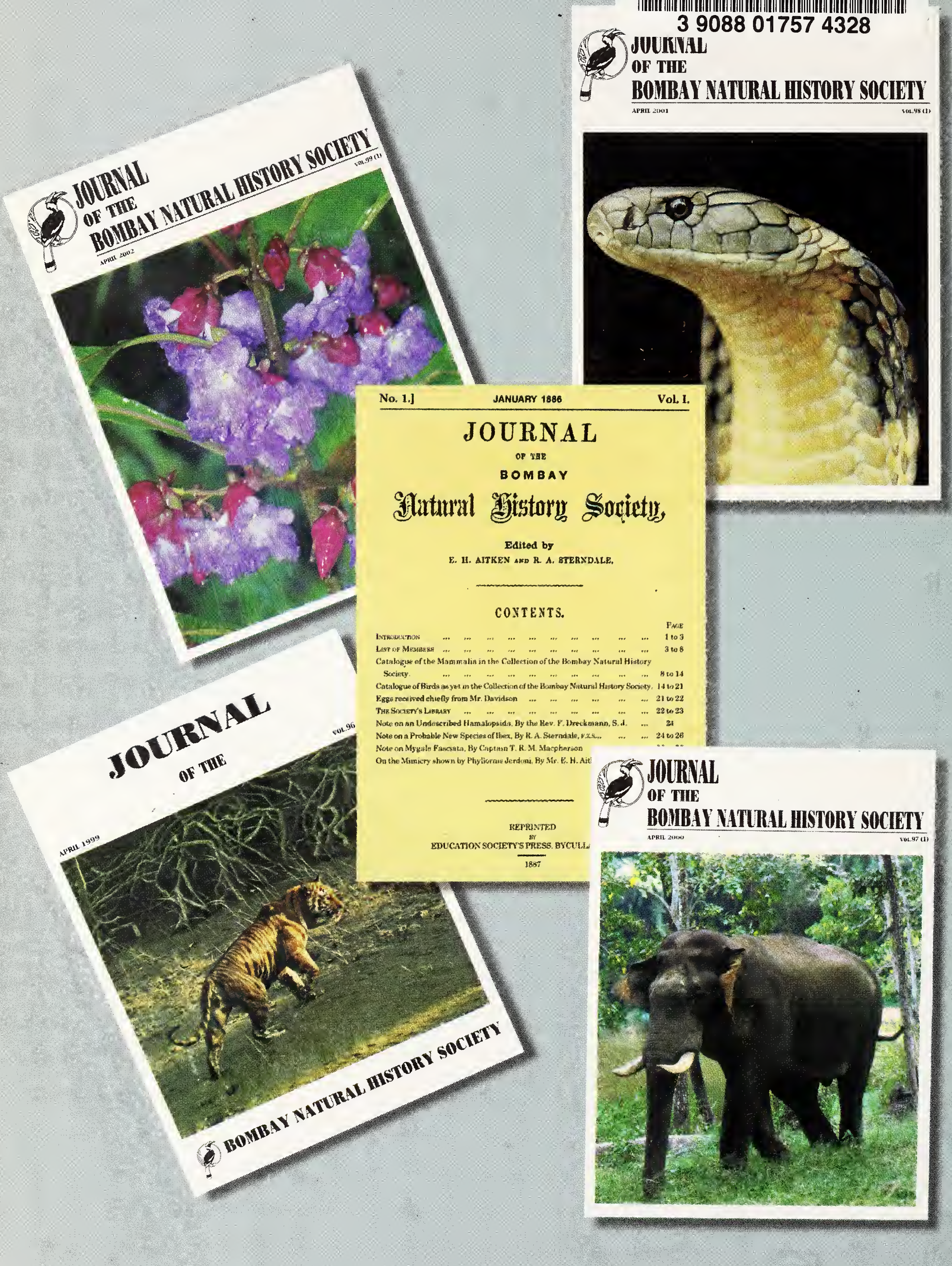
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